The Radiological Society of North America is an association of users of X-ray apparatus and the like, in connection with the practice of medicine. It has been active in attempts to improve the present X-ray tube trade conditions and to secure relief from the present burdensome monopolies on apparatus and supplies useful in the practice of medicine. It is composed of upwards of thirteen hundred leading members of the medical and teaching professions, users of X-ray and radiological appliances, each of whom will, under the decision and decree of the Court below in the instant case, be subject to an extension of the burden of a monopoly already too heavy for the medical profession, and the public served thereby, to bear. It is a fact appearing in this record that the General Electric Company has already been enjoying patent protection on X-ray tubes since 1916, under the Coolidge X-ray tube patent (Deft's. Ex. 67, Rec., Vol. VI, pp. 1021-1029), which protection will be extended for nearly ten years under the Langmuir patent, if the decree below is permitted to stand (Rec., Vol. II, p. 1281; this brief, pp. 37, 38). It will be apparent that each member of the public treated by any appliances involving high vacuum tubes will be subject to the burden of this monopoly, although the General Electric Company has already reaped all the rewards to which it is entitled by virtue of any invention involved under the Coolidge patent. It is also to be noted that it appears in this record that the Coolidge invention was nothing more than the application of the high vacuum tube to the X-ray art (Coolidge, Rec., Vol. III, pp. 1514, 1546).

The Radiological Research Institute is an association of workers interested in the development of X-ray tubes and kindred instrumentalities useful in the practice of medicine and is affiliated with the Radiological Society

referred to above, and is engaged in research directed toward obtaining relief from the monopoly of the General Electric Company in this field. The effect of the decree below is to permit the blanketing of all this work by a patent issued more than twelve years after the stated date of conception of the alleged invention.

In addition to the effect of the decree below upon the X-ray field, it has a serious and far-reaching effect upon the field of radio communication and the public served thereby, as will appear from the following:

This Court (*Westinghouse* v. *DeForest*, 278 U. S. 562) has held the DeForest patents, Nos. 1,507,016 and 1,507,017, to cover basic inventions of DeForest, and has thus made ownership of rights under these patents a necessary prerequisite to the manufacture of vacuum tube transmitting apparatus, which is essential in modern commercial radio transmission. It is impossible to compete commercially in the field of radio communication without operating rights under these patents.

The only person outside of the so-called Radio Corporation group (which includes the General Electric Company among others) and the petitioner herein that owns rights under the DeForest patents is the Federal Telegraph Company. In fact, the rights owned by the Federal Telegraph Company under these DeForest patents are broader in scope than those held by any individual member of the Radio Corporation group and even broader than those held by the DeForest Company, the petitioner herein. The Radio Corporation and the Federal Company are the only two persons holding rights under the DeForest patents in the field of radio telegraph communication for tolls.

It is, therefore, upon the Federal Telegraph Company that the hope of the public for a competitive system of

radio communication rests and, in fact, it is due to the Federal Telegraph Company, and the rights that it holds under these DeForest patents, that the Radio Corporation is now subject to the competition of such a system. The rights of the Federal Telegraph Company are being exercised by it in the manufacture and sale of communication material and by the purchaser of such material, The Mackay Radio and Telegraph Company, a controlled company of the International Telephone & Telegraph Corporation, in the operation of its radio system. The public is thus gravely interested in the perpetuation of the existing competitive conditions and therefore in the continued operation of the Federal Company and its customers.

The decree of the Court below would have the effect of depriving the Federal Company and the users of its apparatus of the right to compete with, and of putting a monopoly on radio communication into the hands of the owners of rights under the Langmuir patent—that is, into the hands of the General Electric Company and of its associated Companies, particularly The Radio Corporation of America.

It is concededly impossible to carry on modern radio communication without high vacuum tubes, and since the invention attributed to Langmuir by the Third Circuit Court of Appeals upon the re-hearing is held to be this precise thing without limitation, the entire art will be at the mercy of Langmuir's assignee. The effect of such action upon the Federal Telegraph Company and users of its communication apparatus is clear, as is also the effect upon the other parties to this brief and upon the field each of them serves.

Aside from its effect upon each of the parties to this brief, the effect of the decree below upon the public in-

terest would be far-reaching. Not only would all commercial radio telegraphic communication be delivered into the hands of the Radio Corporation and the entire X-ray tube art be delivered into the hands of the General Electric Company, but in addition to this, and as stated below, large numbers of persons not directly affected by these considerations would feel the result of this decision.

The patent is held by the decree below to cover the so-called vacuum tube used in every radio broadcasting receiving set and in every apparatus for radio communication. The result of this decree would be to put into the hands of the Radio Corporation and its associates a complete monopoly over the vital part of all of such radio apparatus and permit it to exact tribute from almost every family in the United States.

Except upon the payment of burdensome royalties, no manufacturer could build tubes especially suited to his product, and all communication systems, such as those used on airplanes, ships and elsewhere, including those of the Army and Navy, would be subject to their domination.

Counsel signing this brief, appearing on behalf of the parties named above, have, therefore, asked leave to submit this brief, presenting their argument in support of the prayer of the petitioner that the decree of the Court below be reversed, and the decree of the Trial Court be sustained.

SUMMARY OF ARGUMENT.

The definition of the invention suggested by respondent upon the rehearing in the Circuit Court of Appeals and adopted by Judge BUFFINGTON, speaking for the majority of that Court, is as follows (44 Fed. 2nd, 931, at p. 937):

"But a vacuum, or, indeed, change of vacuum, isolated and standing by itself, is not the Langmuir invention, but it is a working tube in which all the elements, cathode, plate, vacuum, so co-ordinate and inter-work that current flow is not * * * objectionably affected by gas. Just what the degree of vacuum shall be is dependent on several elements * * * and cannot be exactly stated. In that regard the specification says: 'The evacuation of the device should be preferably carried to a pressure as low as a few hundredths of a micron, or even lower * * *.'"

Counsel, in this brief, contend:

1. The invention, so defined, is unpatentable because (A) the definition lacks invention over the prior art acknowledged in the patent, and (B) it differs only in degree therefrom.

A. The patent in suit acknowledges the Fleming tube and the DeForest tube. Like the Langmuir tube, both are hot cathode, electron discharge tubes.

Fleming operates below ionization voltages and hence without any ionization effects and by a purely electron flow.

DeForest operates above ionization voltages. The ionization taking place in his tube affects the current flow, in some respects objectionably. By the theory of ionization, it was understood that ionization could be reduced by reducing the gas content (raising the vacuum) in the tube.

The method of raising the vacuum was known before Langmuir.

Therefore it was entirely within the skill of the calling to raise the vacuum (reduce the gas content) when it was desired to reduce the ionization, and to make the com-

pensating changes in current and/or voltage to secure any desired result.

There was no invention involved in what Langmuir did.

B. Furthermore the tube of the patent differs from the Fleming and the DeForest tubes merely in the degree of vacuum.

This was admitted by respondent before the Court of Appeals.

And the result of such difference in degree was not new.

To the man skilled in the art it was the to-be-expected result. According to Hogan, respondent's expert, there is no sudden beginning or sudden stoppage of ionization with changes in the gas pressure. The ionization changes gradually with the gas pressure. The discharge changes correspondingly from one materially affected by ionization to one not objectionably so affected, *i. e.*, a pure electron discharge according to Langmuir's terminology. Hence there is no new result in the reduction of ionization with reduction of gas by raising of vacuum. The alleged invention of the definition is a mere difference in degree, and there being no new result, there is no patentable subject-matter.

2. DeForest and Arnold, working independently of each other and of Langmuir, arrived at the result attained by Langmuir, as the thing obvious to one skilled in the art. Their acts lie athwart a finding of invention.

DeForest, in July and early August, 1912 (then in the employ of Federal Telegraph Company), when confronted by the necessity of avoiding excessive ionization, ordered the further evacuation of his tubes and succeeded in securing satisfactory operation, without objectionable

ionization effects at voltages within the range specified by the patent (materially above ionization voltages).

Arnold, on November 1, 1912, did exactly the same thing, and with an entire appreciation of the scientific principle involved.

Since these two men were able to reach Langmuir's result by the application of the skill of their calling, their acts lie athwart a finding of invention, as Judge MORRIS puts it.

3. Accepting the definition of the invention adopted by the Court below, we find that exact thing in the prior art.

Three workers in the art did the exact thing prior to Langmuir:

(1) J. E. Lilienfeld in his 1910 paper (referred to by Judge MORRIS and Judge WOOLLEY) described a tube and a process, wherein and whereby he attained the invention of the definition with substantial identity. Such identity is admitted by Langmuir. The date is fixed by the publication and is unquestioned.

(2) DeForest in his 1912 tube, referred to under Point 2 of this brief, did the exact thing of the patent.

The identity is denied; but was accepted by the District Court and by Judge WOOLLEY in the Court of Appeals; and is not mentioned by Judge BUFFINGTON.

The date is fixed by the evidence.

(3) Arnold also did the exact thing as shown under Point 2. The identity is practically admitted, and was accepted by both Judge MORRIS and Judge WOOLLEY.

The date is contested, but, we submit, is proven.

Here, we have three instances of prior knowledge and/or use where the identity is clearly shown, and the dates admitted or established by controlling evidence.

Each instance is a complete statutory bar to the grant of a patent, even admitting patentability—which we do not.

4. The alleged invention is nothing more than a statement of the physical principle of pure electron discharge and therefore not patentable.

Claim 9 is broad enough to cover a modern X-ray tube, such as the Lilienfeld tube or the Coolidge tube. The Lilienfeld tube is admittedly the same as the Coolidge tube within the purview of this patent.

The Coolidge X-ray tube is admittedly covered by the patent in suit.

But in the Coolidge tube there is admittedly no space charge effect.

Nor does the 3/2 power law hold.

Nor is the straight line logarithmic plot obtained by plotting the discharge of the Coolidge tube.

All these phenomena are set out in the patent as tests for the presence of the invention.

But they are not present in the X-ray tube claimed to be covered by the invention.

Hence, the so-called "earmarks" do not define the invention as applied to such a tube. They are, therefore, not of the essence of the invention.

There is nothing left of the invention but a tube evacuated so as to operate with a pure electron discharge according to the circumstance of its use, without other limitation than that the voltages applied shall be above ionizing voltages. This limitation merely differentiates from Fleming. The alleged invention is a mere statement of the physical principle and is not patentable.

5. Langmuir's only practical application of the principle of pure electron discharge was to the DeForest tube. This application was anticipated by both DeForest and Arnold. Hence claims directed to this use are void.

Langmuir did not conceive this application of the principle until March 21, 1913. This is shown by his note book.

Both DeForest and Arnold had made this application in 1912.

Even if this application were patentable, (which it is not), it was barred to Langmuir by the earlier knowledge and/or use of DeForest and Arnold.

ARGUMENT.

1. The invention, as defined by the Court below, is unpatentable, because (A) the definition lacks invention over the prior art acknowledged in the patent, and (B) it differs only in degree therefrom.

(A) The definition lacks invention over the prior art acknowledged in the patent.

The patent in suit (Plff's. Ex. 1, Rec., Vol. IV, pp. 1 to 10) states (p. 1, ll. 10-16) that in the tube of the patent the electric current is carried by electrons emanating from the cathode, independently of gaseous ionization, and differentiates thereby from the prior art tubes.

The theory of ionization is set forth (p. 1, ll. 34 to 75) from which it appears that when a definite amount of gas is present in a tube, a voltage of, say, 25 volts will cause the gas molecules to be split up into ions and electrons, whereupon through "the action and interaction of the ions and electrons" conduction of current across the tube is accomplished.

The patent recognizes the prior existence of both the Fleming tube (valve) and the DeForest tube (audion). Both were hot cathode electron discharge tubes. The patentee says (p. 1, ll. 92-102):

> "Another discharge device previously used to some extent was the Fleming valve. This was a two-electrode tube which, so far as I am aware, was always used at voltages well below the voltages at which positive ionization by collision occurs. It was not evacuated in such a manner as to permit it to be used at voltages materially above these ionization voltages without manifesting substantial positive ionization effects."

The audion of DeForest is described in the patent (p. 1, ll. 77-92):

> "The phenomena above described as being characteristic of devices involving gas ionization are taken advantage of in an incandescent cathode device with three electrodes known as the 'Audion.' This device has been used as a receiver for radiotelegraphy and depends in its operation upon the rapid change of the discharge current when gas ionization begins. This point depends upon various accidental conditions which cause such irregularities in the operation of various devices apparently identical that sometimes only one of a considerable number can be used. Ordinarily the gas ionization in the audion begins to be important somewhere between 20 and 30 volts."

From this it will be seen that the Fleming valve operated below the ionization voltages and thus without aid of ionization. He could have had no such aid since no ionization could have occurred. He was operating with a hot cathode from which the electrons emanated and

were drawn over to the anode by the voltage applied at the anode. This was then purely an electronic flow, but below the ionization voltages rather than materially higher as claimed by Langmuir.

That it was within the knowledge of the art that Fleming had a purely electronic flow, is shown by Fleming's article in the Scientific American, published in 1906, in which it is said (Rec., Vol. V, pp. 168, 170, 171):

> "* * * a high vacuum may be a very good conductor, provided that the negative electrode is rendered incandescent. This shows that the obstruction which a high vacuum offers to the passage of electricity is not due to the mere reduction of the matter in the space (that is, to the rarefaction of the gas), but is, in some way or other, largely dependent upon the temperature of the electrodes; the resistance to the passage of electricity through a vacuum can be rendered very small by intensely heating the negative electrode.
>
> * * * * * * *
>
> If we take measurements of the current passing through the vacuum when the negative electrode is an incandescent carbon filament and the other a cold metal plate, and, at the same time, measure the difference of potential between the electrodes, we find that the conductivity, as measured by the ratio of current to voltage, is not constant, but varies with the electromotive force.
>
> * * * * * * *
>
> These electrons cannot escape from the mass when cold, because if they did they would leave it positively electrified. If, on the other hand, we electrify the mass negatively to a high potential and raise it to a high temperature, electrons can escape freely from it. In every mass of matter there is what we may call a certain 'electronic pressure';

> hence, it follows that the resistance which a high vacuum offers to the passage of electricity through it is, in fact, the resistance which is offered to the ejection or drawing out of electrons from the surface of the electrodes.

Since Fleming shows a pure electron discharge passing from the hot cathode to the anode when operated below ionization voltages, and DeForest shows objectionable effects of ionization, in substantially the same kind of a tube, when operated above ionization voltages, it is the contention of this brief that the man skilled in the art knew from the ionization theory that he could reduce the ionization in the DeForest tube while still operating above the ionization voltages, by reducing the gas content (raising the vacuum) of the tube. He knew how to raise the vacuum before Langmuir (Petitioner's Brief, pp. 21-25). So it was within the skill of the calling to avoid the objectionable effects of gas by raising the vacuum. This, we contend, is abundantly shown by the record.

Respondent's expert, Mr. Hogan, testified that the vacuum in the Fleming valve and in the DeForest audion is of the same order—about 1 to 10 microns for the Fleming tube and 5 to 10 microns for the DeForest tube (Rec., Vol. III, pp. 1660, 1677, 1682).

In the extract from the patent quoted above, Langmuir describes the operation of the DeForest audion as due to "the rapid change of the discharge current when gas ionization begins." This is an error. The operation is in fact due to the rapid change of the discharge current when the voltage applied to the tube is changed, exactly as in the Langmuir tube. However, the discharge current in the early DeForest tube, to which Langmuir is here referring, is admittedly increased by the effect of ionization, and this ionization admittedly causes irregularities in the

operation of the tube and limits its usefulness. For the purposes of this section of the brief, therefore, we shall accept Langmuir's description of the operation of the DeForest tube as substantially correct.

When in the DeForest tube the voltage applied was, say, 25 volts, the gas in the tube, according to the theory, was ionized (Langmuir, Rec., Vol. II, p. 1246), and the ions resulting therefrom, by their interaction therewith, caused additional electrons to flow to the anode. This resulted in greater current (Langmuir, Rec., Vol. II, p. 1242), which was taken advantage of in a manner dependent upon the uses to which the tube was to be put. For our purposes here, we may disregard the particular use of the tube.

So long as the amount of ionization remained within definite limits, the tube functioned satisfactorily. But if too much ionization took place, it began to affect the usefulness of the tube (Langmuir, Rec., Vol. II, p. 1242).

From the theory of ionization expressed in the patent (p 1, ll. 40-56; Rec., Vol. IV, p. 2), it is clear that too much ionization could and would be cured by reducing the amount of gas in the tube (raising the vacuum), other things remaining constant (Langmuir, Rec., Vol. II, p. 1243).

With the knowledge that a pure electronic discharge would flow with a definite voltage and current (as in the Fleming valve), and the further knowledge that the amount of ionization at a higher voltage could be reduced by reducing the amount of gas present in the tube, was it not *within the skill of the calling*, when the necessity arose, to conclude that a pure electronic discharge without objectionable ionization effects could be secured at higher voltages (above the normal ionization voltages) by driving the reduction of the gas to the point where no

harmful amount of ionization under the conditions of operation took place?

Let us see what the man skilled in the art would have done if he had been handed a DeForest tube, with the request to eliminate its erratic characteristics while at the same time increasing its power output.

Such a person would have observed at once, upon operating the DeForest tube, that its erratic operation was due to ionization of the gas in the tube (Langmuir, Rec., Vol. II, p. 1242; Arnold, Rec., Vol. I, p. 559). From his work with the Fleming tube, he would know that ionization is not necessary to permit a current to flow in a vacuum from a hot cathode to an anode. From his knowledge of the electron theory, he would know that the flow of current in both the Fleming and the DeForest tubes is made up of electrons, emitted from the hot cathode and passing to the anode under the attractive influence of the voltage applied to the anode. He would therefore have no hesitation in removing the ionization, on the score of stopping the electron flow. Further, he would know that the amount of ionization, other conditions being equal, depends upon the amount of gas present, and that the amount of ionization can be reduced by reducing the gas content. His first thought would therefore have been further to evacuate the tube and thus to reduce the ionization in the DeForest tube to the point where it was not harmful.

He would then consider the effect on the power output of the tube caused by reducing the amount of ionization. The power output is the product of the current flowing through the tube and the voltage applied across the cathode and the anode. He would know that the current flowing through the DeForest tube, ordinarily, was increased (over that flowing in the absence of ionization)

by reason of the presence of the positive ions in the tube between the cathode and the anode. He would know, therefore, that as he reduced the ionization in the tube, he would also reduce the current, assuming other conditions to remain the same. As his problem called for improving the operation of the DeForest tube and also increasing its power output, he would know that he must apply higher voltages to the anode in order to draw more electrons over to the anode, and thus maintain the current at or above its former value—since he had reduced the current for a given voltage when he removed the effect of ionization.

The power output being the product of the voltage and the current, as stated above, it will be apparent that if the voltage be increased sufficiently to bring the current up to the value it had before the increase in the vacuum, the power output of the tube will have been increased. And any further increase in the voltage, with the consequent increase in current, will result in a corresponding increase in power output.

But it may be queried: Will not the increased voltage and current again increase the amount of ionization and put the tube back in the former condition of harmful ionization effect? In order to answer this, we must consider briefly the causes governing the amount of ionization. Ionization is due to collisions between electrons and gas molecules; so anything that tends to decrease the probability of such collisions will tend to decrease the amount of ionization, and vice versa. For the purposes of this case, we may disregard the minor influences of the velocities of the electrons and of the gas molecules, and consider merely the effect of the number of electrons and of gas molecules present in the space between the anode and the cathode. Obviously, an increase in the

number of electrons will tend to increase the number of collisions, and a decrease in the number of gas molecules will tend to decrease the number of collisions. Hence the ionizing effect of any increase in the number of electrons (*i. e.*, an increase in the current flowing) due to an increase in the applied voltage, may be overcome by a suitable reduction in the number of gas molecules (*i. e.*, an increase in the degree of vacuum). Thus we see that a worker skilled in the art would appreciate that he would merely have to increase his vacuum sufficiently to keep the amount of ionization below the harmful limits for the desired conditions of operation.

By way of illustration, let us assume that the current flowing in the DeForest tube, which was the starting point of our skilled worker, was ample for the purposes desired (as indeed it would be for many uses of the modern high vacuum tubes even today). If then we increase the vacuum, resulting in a decrease in ionization and, thus, in current; and *afterwards* increase the voltage to bring the current up only to its former value; there will have been no *net* increase in the number of electrons. There will, however, have been a decrease in the number of gas molecules, and, therefore, a decrease in the amount of ionization over that obtaining originally in the tube. Furthermore, there will have been an increase in the power output of the tube, since, though there has been no net change in the current, there has been an increase in the voltage, and hence in their product. We see, therefore, how simply a man skilled in the art could increase the power output of a DeForest tube and at the same time eliminate its erratic characteristics by reducing the amount of ionization.

There is no invention here over the prior art. The skilled worker has merely applied known principles.

(B) The definition differs only in degree from the prior art acknowledged in the patent.

Furthermore the tube of the patent differs from the Fleming and the Deforest tubes merely in the degree of vacuum obtaining in the tube. It was categorically admitted by respondent that the *only* difference between the DeForest tube and the Langmuir tube was that in the latter the gas had been reduced to a pressure of a few thousandths of a micron. This admission appears in its brief before the Court of Appeals at the first hearing, as follows (p. 30):

> "On the other hand, the invention may be realized by 'producing and maintaining', as the District Court put it, a pressure of a few thousandths of a micron in a DeForest audion."

There is no reference here to structure or geometry, because all of this is admittedly present in the prior DeForest tube.

A mere difference in degree is not patentable, unless some new and unexpected result is obtained. As we understand respondent's position, it contends that Langmuir obtained, by reason of this increase of vacuum, a pure electron flow substantially unaffected by ionization at voltages materially above the ionizing voltages, and that this was a new and unexpected result. We shall show in a separate section of this brief (p. 28 to p. 36) that Langmuir was not the first to obtain such a pure electron flow in a hot cathode vacuum tube; but for the purposes of this point, we shall assume that he was the first to do so.

It is clear from the record that there is no sharp line of demarcation between an electron flow substantially affected by ionization, as in the DeForest tube, and a

pure electron flow as obtained and defined by Langmuir (this brief, pp. 24-25). As Mr. Hogan, respondent's expert, testified on direct examination (Rec., Vol. III, p. 1722):

> "If we leave the voltage the same and the electron current the same, and gradually increase the pressure, the gas pressure in the tube, the ionization in the tube will gradually increase. As we have all recognized, there is some measurable ionization, even below points at which ionization harmfully affects the space charge. There is no sudden beginning or sudden stoppage of ionization as a physical fact."

Conversely, as the gas pressure in a DeForest tube is gradually reduced (vacuum gradually increased), the amount of ionization will be gradually reduced until finally and inevitably we reach a point where the current flow is no longer objectionably affected by ionization. At this point we have a Langmuir tube operating with a pure electron discharge. The mere statement of this gradual change in cause and effect shows conclusively that there is no difference in kind. It is a mere difference in degree of vacuum, and the same thing is equally true as to the discharge. There is no difference in kind of discharge—it is always an electronic discharge—it differs only in the degree to which it is affected by the ionization changing with changing vacuum.

Since the alleged invention differs only in degree and no new or unexpected result was secured, there is no patentable subject-matter present and the patent is void.

2. DeForest and Arnold, working independently of each other and of Langmuir, arrived at the result attained by Langmuir, as the thing obvious to one skilled in the art. Their acts lie athwart a finding of invention.

DeForest.

DeForest in 1912 was employed by the Federal Telegraph Company, which at that time was operating a commercial radio telegraph service on the Pacific Coast (Rec., Vol. II, p. 1050). Its service demanded the best available apparatus, and DeForest, among others, was employed to perfect this service (Rec., Vol. II, p. 1045). Federal Telegraph Company in 1912 was employing DeForest tubes in amplifiers used in connection with high speed recording apparatus in its commercial work (Rec., Vol. II, pp. 1045, 1046, 1051).

In 1912, DeForest was confronted with a situation in which he found his tubes, in commercial operation, showing the effects of too much ionization. He knew at once that he needed to reduce the amount of gas present. So he ordered these tubes evacuated to a higher degree (Rec., Vol. II, pp. 1052, 1059). As a result of such further evacuation, he was able to apply a higher voltage and secured a result substantially free from objectionable ionization effects.

The record contains contemporary written evidence of DeForest's desire for a higher vacuum in his tubes and of the improved results obtained thereby. Under date of July 26, 1912, DeForest wrote to the McCandless Company (which was then manufacturing DeForest tubes for the Federal Telegraph Company) as follows:

> "Out of the last lot of 24 audion bulbs which you manufactured for us there are only 4 that came up

> to *proper sensitiveness test. Apparently the vacuum in the other bulbs is too low, because in these latter bulbs we notice that the blue arc or cathode beam starts suddenly at 15 or 20 volts, under which condition the bulb is not sensitive"* (Deft's. Ex. 79-A, Rec., Vol. VI, p. 1061). (Italics ours.)

Shortly thereafter, on August 14, 1912, DeForest wrote again to the McCandless Company, saying:

> "We took two of the poorest of the discarded 20 to a San Francisco glass-blower, unknown to fame, *and had him exhaust same to as high a vacuum as his pumps would take.* These reexhausted bulbs now show a sensitiveness equal to those of the first four, *which proves conclusively that our contention is correct. For the work which we demand from these bulbs they are not sufficiently sensitive—and we would be glad therefore if you will reexhaust them.* You certainly should be able to put them in as good condition as the aforesaid San Francisco glass-blower" (Deft's. Ex. 79-B, Rec., Vol. VI, p. 1062). (Italics ours.)

The evidence is clear that these tubes, re-evacuated by the San Francisco glass-blower (Lamont by name), were used by the Federal Telegraph Company in its commercial operations at voltages running up to 54 volts (Tuel, Rec., Vol. II, p. 1052). There is also testimony that an amateur named Hewlett used similar tubes, evacuated by Lamont, at voltages in excess of 60 volts (Hewlett, Rec., Vol. II, p. 1008).

Naturally enough, no evidence was available as to the so-called "earmarks" or characteristics of the discharges in these Lamont tubes. These workers were not hunting for material to put in patent applications. They knew there was nothing patentable here. Lamont and others,

however, testified in detail (Lamont, Rec., Vol. II, p. 1027, *et seq.*) as to the thoroughness of their evacuation, which followed in large part the procedure subsequently recommended by Langmuir (Lamont, Rec., Vol. II, pp. 1029, 1030). It was undoubtedly proven (Tuel, Rec., Vol. II, p. 1053; Watkins, Rec., Vol. II, p. 1055) that the tubes operated satisfactorily at the voltages mentioned. These voltages are not only "materially above ionization voltages" but are considerably above the lower limit of 40 volts set by Langmuir for his invention in claim 26 of his patent.

It is clear from the record that since these tubes operated *satisfactorily* at these high voltages, they must have operated without harmful ionization (Langmuir, Rec., Vol. II, p. 1263; Hogan, Rec., Vol. I, p. 97, Vol. III, pp. 1713, 1714). As satisfactory operation is the only essential test of the presence of the Langmuir invention (Langmuir, Rec., Vol. II, Q200, particularly pp. 1239-1240), these tubes had the discharge of the Langmuir tube. Dr. Langmuir defined a pure electron discharge, the presence of which respondent contends evidences a Langmuir tube, as follows (Rec., Vol. II, p. 1350):

> "Of course, the word pure is always a relative term which denotes a comparison between one thing and another. When I talk of pure electron discharge I have usually meant a discharge in which the effects of ionization do not materially influence the usefulness or characteristics of the device as it is to be used. That is what I think we always mean by purity."
>
> * * * * * * *
>
> "As I understand the word pure it means free from harmful ingredients or harmful effects and of course that necessarily implies that the very word harmful means harmful for some purpose.

> "Ionization always occurs in all tubes at voltages materially above the ionizing voltage. So to some extent no electron discharge can be absolutely pure. There will always be some ionization. So that by the word pure we necessarily mean free from ionization to an extent that is such that the ionization bring about no harmful or deleterious action."

DeForest in his 1912 tubes secured a vacuum such that the ionization present brought about no harmful or deleterious action, and may, therefore, properly be said to have arrived at the same point as did Langmuir in the alleged invention of the patent.

It certainly did not amount to invention for Langmuir subsequently to discover and set down the "earmarks" or characteristics of that tube. This is a mere matter of scientific observation.

Arnold.

On November 1, 1912, Arnold did exactly the thing that DeForest had done earlier in the same year. He was shown a DeForest audion that amplified weak telephone currents beautifully at low voltages, and functioned at those low voltages without harmful ionization (Arnold, Vol. I, pp. 555, 556, 567); but the currents were distorted and the tube failed to function in a suitable manner when higher voltages (higher power outputs) were attempted (Arnold, Rec., Vol. I, p. 560). He was asked how the tube could be made to operate properly as a telephone amplifier at the higher powers necessary in telephone work. Although he had never before seen an audion, he was acquainted with it from the literature (Arnold, Rec., Vol. I, p. 556), and he at once responded that the difficulties experienced were due to ionization of the residual gas, and that the difficulties could be eliminated and the

ionization reduced until it was harmless by increasing the vacuum (Arnold, Rec., Vol. I, p. 559). He also made other suggestions, principally directed to improving the structure of the tube, but they are immaterial here (Arnold, Rec., Vol. I, p. 557).

Arnold was the representative "man skilled in the art", of whom we have spoken heretofore, and his reasoning and his conduct were exactly those that we described earlier (this brief, pp. 17 to 19) as to be expected of such a man. It did not occur to him that he had made an invention or that there was anything patentably new about this idea. As stated by Judge Morris in the District Court (Rec., Vol. III, p. 1964):

> "Moreover, the fact that falls but little short of a demonstration that the employment of the known pure electron discharge above ionization voltages in tubes of the DeForest type was but the availment of those skilled in the art of the store of knowledge that had been accumulated and lay ready at hand is that when Arnold, who had had long experience with electrical discharges in high vacuum, was shown a DeForest audion for the first time on November 1, 1912, and saw it in operation he immediately realized and said, in effect, that by increasing the vacuum the discharge would be sufficiently stable and at adequate power levels to enable the tube to be employed as a relay device in trans-continental telephony. While not unmindful that invention may sometimes be the result of an instantaneous happy thought, yet the state of the art is strongly confirmative of Arnold's own view at the time that the improvement suggested by him was obvious to one skilled in the art. The act of Arnold turns the scale so overwhelmingly that it lies athwart a finding of invention."

Like DeForest, Arnold appreciated at once that to use higher voltages and thus obtain increased power, he must employ a higher vacuum. Arnold probably knew more than DeForest about the underlying principles of operation of the tube, since the latter was more of an experimenter and perhaps not as highly a trained physicist, as was Arnold. But both men reached identically the same conclusion, and both considered the increase in the vacuum as merely a manufacturing expedient to fit the tube to the desired use. Both knew that the higher the voltage to be applied, the higher the vacuum should be. Very likely DeForest had no full realization of the extent to which the improvement in vacuum and the corresponding improvement of the tube could be carried, but he nevertheless succeeded in obtaining a tube of the patent that was satisfactory for his then purpose. Arnold, on the other hand, fully appreciated the electrical phenomena involved, and was able forthwith to carry the thought to its logical conclusion of substantial elimination of ionization.

On the strength of his recommendation, Arnold was at once authorized by his superiors to organize a department of the Telephone Company with the end in view of adapting the DeForest audion to the requirements of telephone service (Arnold, Rec., Vol. I, pp. 594, 595, 601). This ready and immediate acceptance of the suitability of a more highly evacuated DeForest audion for use in the telephone circuits is eloquent of the certainty of Arnold and his associates and equally of the obviousness of the higher evacuation. Before the end of the month, Arnold had improved the vacuum in one of the original tubes left with the Telephone Company by DeForest to the extent that it operated with a pure electron discharge fully within Langmuir's definition (Arnold, Rec., Vol. I,

pp. 599, 603); and it operated satisfactorily up to 80 volts (Arnold, Rec., Vol. I, pp. 597, 598). This was the so-called Audion 7-A (Arnold, Rec., Vol. I, pp. 596, 603). The increased vacuum was obtained not by opening the tube and repumping it, but simply by using the phenomena of "clean-up," already familiar from incandescent lamp practice (Arnold, Rec., Vol. I, pp. 596, 597, 602). This tube completely demonstrated the correctness of Arnold's conclusions, and left him free to proceed with the problems of improving the mechanical design and life of the tube and fitting it into the existing telephone network. It also makes it unnecessary for us to consider his later work, since we are interested only in showing that he did a thing obvious to one skilled in the art, and hence unpatentable. Since what Arnold did, in the exercise of the skill of his calling, was exactly the sum total of Langmuir's accomplishment, it follows that the Langmuir patent is void for want of invention.

3. Accepting the definition of the invention adopted by the Court below, we find that exact thing in the prior art.

The Court of Appeals adopted the following definition of the invention: "It is a working tube in which all the elements, cathode, plate, vacuum, so coordinate and interwork that current flow is not objectionably affected by the gas." We accept this definition and find this exact thing in the prior art.

For the purposes of this section, we shall also accept the position of the respondent that gas takes part in the conduction of current in the DeForest tube; but we do not agree that it is proper to speak of gas as a conductor. However, from our point of view, the controversy over

the use of the term "gas conduction" has no place in the discussion of this point.

There is no disagreement that, in the tube of the patent, gas does not take part in the conduction of the current to any material extent. We shall pass, for the moment, the question whether the differences between the Langmuir tube and the early DeForest tube amount to invention; and we look to the prior art for that which has the substantial identity of the claimed invention, according to the Court's definition. We have no difficulty in finding three prior workers in this art who have each done the same thing in substantial, or exact, identity.

The first one was:

J. E. Lilienfeld.

When we read the admissions of Langmuir in the record (quoted by Judge WOOLLEY in his dissenting opinion and reproduced by petitioner in its brief, pp. 31, 32) we wonder what there is left to be said, honestly, about the claimed invention in this case.

For example:

There is the admission by Langmuir that

> "Lilienfeld probably succeeded in obtaining a discharge in high vacuum substantially free from the effects of positive ionization in the device he described in his 1910 paper."

No importance is placed by respondent on the word "probably".

The degree of vacuum attained by Lilienfeld is abundantly proven in his 1910 paper (Deft's. Ex. 25, Rec., Vol. V, p. 315). It is not understood that there was any intention to qualify in this respect either. In a further answer Langmuir admitted that Lilienfeld, in many of

his experiments, realized a condition "where the lowering of the (gas) pressure (was brought) to such a point *that a further lowering brings about no further change.*" It was the same order of vacuum as Langmuir's. And as Langmuir again admitted, "the effects he (Lilienfeld) measured were not dependent upon gas ionization."

We cannot seriously consider as controlling the words "working tube," in the definition adopted by the Court below. The Court below based its finding of invention on *commercial use.* But the fact of commercial use is only helpful in case of serious doubt. If there is substantial identity in a prior knowledge, it is immaterial whether there was commercial use of the prior knowledge. This point was settled in this Court in the case of *Corona Co. v. Dovan Corp.*, 276 U. S. 358. Of course, the prior art device must have functioned in order that it be complete. But for the purposes of this case, the knowledge of the invention of the definition is complete when there is present a tube of substantially the construction of the broadest claims and in which there is an electron discharge free from objectionable effects of gas, working above ionization voltages.

What have we in the Lilienfeld disclosure? We have a tube used as an implement of research, but answering to the terms of the claims of the patent, and consequently anticipating them. While the device was experimental, the adaptation of the device to any commercial purpose contemplated by the patent, was obvious. In the sense that it produced a discharge of reproducible character, it was a "working tube." It had a hot cathode and an anode. Its vacuum was higher than required by the patent. Certainly it was higher than a few hundredths of a micron. And the coordination of the cathode and anode and of the vacuum under appropriate voltage (far

above the ionizing voltages—Hogan, Rec., Vol. III, p. 1703) was such that the current flow was not objectionably, if at all, affected by gas.

It is difficult to understand how the respondent here can face the disclosure of J. E. Lilienfeld and persist in the claims of invention.

It will not do for the respondent to refer to the work of Lilienfeld as mere laboratory experiments. In the *Corona* case (276 U. S. 358), this Court has made clear the law with respect to prior knowledge as evidenced by laboratory work. If the substantial identity of the earlier work is established, it is a complete bar to a patent for the later invention, provided it has worked on any scale.

And moreover, if Langmuir's laboratory tubes and experiments may be the basis of his claim for a patent here, the equivalent work of Lilienfeld is an equally justifiable basis for establishing anticipation. Langmuir is subsequent to Lilienfeld in the essence of his invention. So the patent is invalid.

It would seem that patentability was found by the Law Examiner in the Patent Office not in discovering or producing anything new, but in perceiving the practicability of scientific facts known in the laboratory and in making practical useful devices embodying the scientific laws known in the laboratory. (See opinion of Commissioner of Patents in the Interference, blue pamphlet, pp. 10, 11.) It is true that there may be inventive subject-matter in such practical application of a principle. But if a tube is shown, as by Lilienfeld, in which the principle of pure electron discharge is clearly disclosed, can the subsequent inventor foreclose the prior discoverer of the right to make such use of his discovery as he sees fit? Of course, the particular use made of the principle may be monopolized by the subsequent inventor. But the subsequent in-

ventor cannot thereby usurp all applications of the principle, even though the first discoverer had failed to put into force any practical application of his invention to the useful art. As a matter of fact, Lilienfeld did subsequently make such an application of his discovery to the X-ray art, and of this, we will treat in a later portion of this brief (pp. 38-40).

However, no such following up in any way affects the force or effect of the laboratory work as an anticipation. As was said by Chief Justice TAFT in the *Corona* case (276 U. S. 358, at p. 384):

> "It is a mistake to assume that reduction to use must necessarily be a commercial use. If Kratz discovered and completed, as we are convinced that he did, the first use of D.P.G. as an accelerator in making vulcanized rubber, he does not lose his right to use this discovery when he chooses to do so, for scientific purposes or purposes of publication or because he does not subsequently sell the rubber thus vulcanized, or use his discovery in trade, or does not apply for a patent for it. It is not an abandoned experiment because he confines his use of the rubber thus produced to his laboratory or to his lecture room. It is doubtless true that Kratz, by his course in respect to his discovery as to the use of D.P.G., has abandoned any claim as against the public for a patent, but that is a very different thing from saying that it was abandoned as against a subsequent discoverer or patentee."

The sole question here is whether what Lilienfeld did was in principle the same as that performed by Langmuir. If the identity is established, there is prior knowledge, and there cannot be, under the *Corona* case, any question of abandonment. And there cannot be any question of commercial use. If Lilienfeld, knowingly, has a completed

thing, no one can, by subsequent act, exclude him from the use of that completed thing except by, and to the extent of, adding a further novel thing, in patentable coaction, to the thing completed by Lilienfeld. Therefore, we say that, if Lilienfeld has produced a tube with elements, the equivalent of Langmuir's elements, no amount of subsequent commercial application of substantially that thing can detract in any way from the exact quality of Lilienfeld's act. Whatever may have been the law before the *Corona* case, thereafter the statement by the Law Examiner is not the law as applied to this case.

In a subsequent section of this brief we will consider Langmuir's claims in connection with the X-ray tubes of Lilienfeld. But at this point, it is sufficient to point out that Claim 11 is broad enough to cover any tube in which the elements are the same as in the Lilienfeld experimental tube; and wherein the vacuum and the voltages are of the same order and relation. All that is stated, as the result, is that a pure electronic discharge shall be obtained free from appreciable effects of gas. That is the admitted result of the Lilienfeld tube. And unless there is added to the elements and vacuum and voltage of the Lilienfeld tube something novel and useful, and in inventive coaction with them, then no subsequent act of Langmuir can affect the quality or effect of Lilienfeld's act. It makes patenting of that thing to Langmuir impossible.

The next worker to do the same thing was

DeForest.

We have heretofore in this brief (pp. 22 to 25) described the DeForest work in 1912. For the purpose of this point we need only call attention to the fact that the precise tube of the patent was evacuated in such a way as to enable an electron discharge to be obtained substanti-

ally above ionizing voltages without objectionable effects from gas. If the facts are accepted, as they were by the District Court, then there can be no question that the invention of the definition adopted by the Circuit Court of Appeals was present in the DeForest 1912 tube, intentionally, purposely and commercially.

It is solely a question of fact, and we refer here to our discussion on pages 22 to 25 of this brief, and to the discussion of the same facts in the opinion of the District Court (Rec., Vol. III, pp. 1965, 1966). We are able to find but one conclusion on this issue of fact. The invention of the definition was present in the DeForest work in 1912 and prior to Langmuir.

And the third worker, knowingly and intentionally, doing the identical thing was

Arnold.

On pages 25 to 28 of this brief, we have attempted to show that in November, 1912, Arnold, too, completely developed the invention of the definition. He produced a tube of the exact construction of the tube of the patent and obtained an electron discharge substantially above ionization voltages without objectionable effects of gas.

If the facts of the existence of the tube and its operation are accepted, then there remains no problem—except that of date—for here, as in the DeForest use, the identity of the thing is complete. Moreover, it was intentionally and purposely created, and the principles of its operation were fully understood.

This work by Arnold was commenced on November 1, 1912, and was completed before Langmuir first saw a DeForest tube in February of 1913. It was prior to the work in November, 1912, first alleged by Langmuir as his conception and reduction to practice of the invention, in his

sworn preliminary statement in the Interference proceeding in the Patent Office. However, the Arnold work was subsequent to the August, 1912, conception date, later advanced by Langmuir. It is, therefore, necessary to consider for a moment Langmuir's August, 1912, work, which was the only work by Langmuir on the invention contended by respondent to have preceded the latter part of November, 1912, specifically November 19th, 1912.

In the August work, Langmuir had a vacuum tube constructed like an incandescent lamp with two filaments, one of which he heated in the ordinary way, and the other of which he kept cold (Langmuir, Rec., Vol. II, p. 1116). Nitrogen was introduced into the tube, and a discharge caused to pass between the hot filament as a cathode and the cold filament as an anode by applying a potential of about 250 volts therebetween (Langmuir, Rec., Vol. II, pp. 1122, 1124). Langmuir was then interested only in studying the rate at which the nitrogen was "cleaned up" or caused to disappear by the discharge between the cathode and the anode (Langmuir, Rec., Vol. II, pp. 1116, 1122). When the nitrogen pressure reached a value of about 0.4 of a micron, the discharge current fell to a low value (Langmuir, Rec., Vol. II, pp. 1125, 1126). The tube was then refilled with the nitrogen gas for further experiments (Langmuir, Rec., Vol. II, p. 1130).

Respondent now contends that Langmuir had a pure electron discharge unaffected by ionization when the nitrogen pressure was reduced to its lowest value of 0.4 micron as described (Langmuir, Rec., Vol. II, pp. 1128, 1302). But Langmuir admits that he was not then conscious of this alleged fact. He testified in this case on that point as follows (Rec., Vol. II, p. 1328):

> "Q380. You did not know at the time or you did not suppose at the time that you had a pure elec-

tron discharge substantially unaffected by positive ionization, did you?

"A. No, I did not draw that conclusion at that time. I know now but I did not know it then."

It is so clear as to require no argument that there can be no *con*ception of an invention without *per*ception of it (Robinson on Patents, Vol. I, Sec. 79, p. 121).

It should be noted that, in these August experiments, Langmuir merely reached the point, even if his contentions be granted, where pure electron discharge commenced. This condition he was not then interested in, so he introduced more nitrogen gas and retraced his steps. Instead of exploring the new field of pure electron discharge contended to have been opened to him, he closed the door on that field by the introduction of gas, and continued his study of gas clean-up effects.

It follows that Langmuir can be awarded no date earlier than the November 1, 1912, date of Arnold.

We conclude that in view of the work of Lilienfeld, DeForest and Arnold, there is no room for the invention of the definition. Even the fact of *commercial use* implied in the words "working tube" can avail the patentee nothing, for there is no room for doubt; and it is only in cases of grave doubt as to invention accompanied by no direct evidence of prior use, that the factor of commercial use is to be considered. As Judge MORRIS points out (Rec., Vol. III, p. 1964) the radio art was young in 1912. Fleming had no need for this alleged invention. The DeForest audion was not in evidence. There was no long-felt want. The evidence of utility, here, is indicative of nothing more than a proper natural development of the art. Lilienfeld, DeForest and Arnold did the exact thing prior to Langmuir.

The patent is void.

4. The alleged invention is nothing more than a statement of the physical principle of pure electron discharge and therefore not patentable.

The definition of the invention adopted by the Court below and the claims of the patent are broad enough to include modern X-ray tubes. Indeed, respondent contends in this case that the Langmuir patent dominates the Coolidge X-ray tube.

Claim 9 is typical of a group of claims of such breadth. It is as follows:

> "9. A discharge tube having a cathode adapted to emit electrons, an anode adapted to receive electrons and tube walls fashioned, or shaped, so as to permit the free passage of a useful proportion of said electrons from cathode to anode, the gas content or residue of said tube and the relation of the parts of the tube being such that the tube is capable of operation with stable and reproducible results substantially unaffected by positive ionization, with currents of at least 5 milliamperes and with voltages of at least 200 volts."

Analyzing this claim we find:

(1) A discharge tube

(2) Cathode adapted to emit electrons

(3) Anode adapted to receive electrons

(4) Free passage for electrons from cathode to anode

(5) Vacuum such as to permit operation with reproducible results

(6) Substantially unaffected by ionization

(7) With currents of at least 5 milliamperes

(8) With voltages of at least 200 volts

The construction of the tube described is clear. We are merely to have a free passage for electrons from a hot cathode to an anode. The vacuum is simply to be such as is necessary (whatever that may be) to secure "stable and reproducible results," by avoiding ionization under the conditions of operation. These conditions are that the current strength shall be *at least* 5 milliamperes, and that the voltage shall be *at least* 200 volts. It will be seen that there is no upper limit on either the current strength or the voltage.

This claim completely covers the Coolidge X-ray tube and the Lilienfeld perfected X-ray tube, both of which admittedly operate with a pure electron discharge, at currents greatly in excess of 5 milliamperes and with voltages running to many thousands of volts.

The period between the publication of Lilienfeld's 1910 article describing his experimental discharge tube (discussed above in this brief, pages 29 to 33) and the perfection of the Lilienfeld X-ray tube referred to above, was occupied with the usual process of development from the 1910 experimental tube to the finished commercial Lilienfeld X-ray tube.

Respondent's admission with respect to the operation of the perfected Lilienfeld X-ray tube is contained in a footnote on page 99 of its brief on the first hearing in the Circuit Court of Appeals, as follows:

> "A later form of Lilienfeld tube was first described *after* the publication of the Coolidge tube (Vol. III, pp. 1698-1700). This tube did not require ionization for its operation; if properly designed and properly evacuated it would be operable with the Langmuir vacuum.
>
> "This last tube of Lilienfeld's, the only one which, so far as we know, ever went into really practical

use at all, resembles the Coolidge tube much more closely than it does the tube described in the Lilienfeld-Rosenthal paper. Instead of Coolidge or Langmuir learning something from Lilienfeld, it was Lilienfeld who learned from Coolidge and Langmuir."

Further respondent says, commencing on page 100 of the same brief:

> "If Lilienfeld's publications, plus all the work which Lilienfeld did, did not teach Lilienfeld to build a hot-cathode, pure electron discharge tube—and they did not—that fact alone would outweigh a thousand pages of expert testimony to the effect that they *ought* to have taught him, and anybody else skilled in the art, how to do it (*Schmertz Wire Glass Co.* v. *Pittsburgh Plate Glass Co.*, 168 Fed. 73, 77)." (Italics respondent's.)

Respondent is entirely unwarranted in concluding that the Lilienfeld perfected tube, referred to, owed any part of its being to contributions from either Langmuir or Coolidge. The portions of the record (Vol. III, pp. 1698-1700) cited by respondent, refer to various publications describing the improved Lilienfeld tube, but nowhere is it stated that these were the *first* publications of that kind. Indeed, it is a fact within the available knowledge of counsel who wrote that brief, that this tube was invented by Dr. Lilienfeld before November, 1913, the date of the application in Germany for the Lilienfeld patent covering that pure electronic discharge X-ray tube. That he could not have been assisted by either Coolidge or Langmuir in this development, is shown by the fact that the first publication of their work occurred in December, 1913 (Deft's. Ex. 66, Vol. VI, p. 919; Plff's. Ex. 21, Interf. Ex. 2).

Thus it appears that Lilienfeld's publications and his work did teach him how to build a practical, hot cathode, pure electron discharge X-ray tube, and that Lilienfeld diligently followed up the transformation of his laboratory work into successful commercial products. As respondent so aptly says, these facts speak louder "than a thousand pages of expert testimony."

We see from the foregoing that the interpretation of the patent contended for by respondent and made by the Court below, gives it a scope covering the application of *the principle of pure electron discharge* to practical devices in an art to which Langmuir made no real contribution. In other words, although Lilienfeld disclosed the principle prior to Langmuir, he is, according to respondent's argument, to be prevented from applying that principle to the practical X-ray art, because, forsooth, Langmuir preceded him in the practical application of the principle to quite another art. We submit that this would be a manifestly unjust result, based upon an untenable proposition of law entirely *contra* to the *Corona* case and to the accepted principles underlying our patent structure.

The same result may be reached from a somewhat different aspect.

In the Coolidge tube, admittedly dominated by the Langmuir patent, the voltages employed are so high that practically all of the electrons emitted by the hot cathode are drawn over to the anode (Coolidge, Rec., Vol. III, p. 1556). This is referred to in the patent in suit as operation in the saturation range (p. 2, ll. 77 to 95). But this means that the space charge effect of claims 1 and 10, for example, is without influence on the operation because there is no surplus of electrons on which the space charge can act (Coolidge, Rec., Vol. III, p. 1557). Since the volt-

ages are high, in the saturation range, the discharge does not follow the so-called 3/2 power law of claims such as claim 6. Nor is the straight line logarithmic plot of claim 4 obtained by plotting the discharge of the Coolidge tube. These are stated by respondent to be "earmarks" of the Langmuir invention.

What this means, in simple language, is that none of these complicated phenomena can be accepted as sufficient tests for the presence of the invention, since the invention is claimed to exist in a tube lacking all of them. It follows, therefore, that such things are not of the essence of the invention. But when we look behind them to find the essence of the invention, nothing is left but a vacuum tube having a pure electron discharge, without limitation as to its construction, operation or application to use, other than that the voltages applied shall be above the ionizing voltages. This limitation has no other force than to differentiate from Fleming, who has a pure electron discharge below ionizing voltages, and, therefore, without ionization effects, objectionable or otherwise.

We have, then, a situation where what actually is claimed is the physical principle of pure electron discharge, quite aside from its practical application to any particular art. We have shown above that this principle, this type of discharge, was not new with Langmuir. But wholly apart from this, it is inherently unpatentable subject-matter. It is neither an art, nor a machine, nor a composition of matter. The claim is artfully worded in terms of an article of manufacture, but it defines the article only by the characteristics of its discharge—the principle of its operation.

This is no more patentable than the law of gravitation.

5. Langmuir's only practical application of the principle of pure electron discharge was to the De-Forest tube. This application was anticipated by both DeForest and Arnold. Hence claims directed to this use are void.

If we accept the proposition that patentable invention in this case must be limited to the application of the principle of pure electron discharge to a particular practical use, the only such application by Langmuir was to the three electrode DeForest audion. But this application was not even conceived by him until March 21, 1913, long after the same practical use had been made by both De-Forest and Arnold. (This invention is claimed only in claims 10, 12, 18, 19, 21 and 22 of the patent.)

It is true that respondent does contend to have developed, as coming within the alleged Langmuir invention, the Coolidge X-ray tube, and the Kenotron high voltage alternating current rectifier, as well as the high vacuum three electrode tube corresponding structurally to the De-Forest audion. But we assert that this contention is unfounded.

The Coolidge X-ray tube is the development of Dr. Coolidge, and respondent is estopped to deny that it is Coolidge's invention by having taken out the Coolidge patent thereon (Deft's. Ex. 67, Rec., Vol. VI, p. 941).

The Coolidge X-ray tube, as pointed out above (this brief, p. 40), is a high voltage tube. It is not disputed that it is inherently a rectifier, and that the Kenotron rectifier is an outgrowth of the "Coolidge tube" (Rec., Vol. III, pp. 1528, 1529). The Kenotron rectifier is in fact essentially a Coolidge tube arranged in the high voltage circuit in such a way that the X-rays generated are of low penetrating power and do not get through the glass walls

(Coolidge, Rec., Vol. III, pp. 1529, 1530). There is nothing in this record to indicate that Langmuir had anything to do with its development, and from the logic of the situation, it is clear that he played no such part.

The low voltage rectifiers, say, of the order of a few hundred volts, in commercial use today, such as the Tungar rectifier of respondent, are admittedly gaseous tubes, and are in fact merely structurally improved Fleming valevs. It is admitted in this record (Langmuir, Vol. II, pp. 1351, 1352) that such tubes operate better with gas, and that they are outside of Langmuir's alleged invention.

This leaves us only the high vacuum DeForest tube. Langmuir testified that he first saw a DeForest tube in February, 1913 (Rec., Vol. II, p. 1182). Shortly thereafter he built several such tubes and experimented with them. While there is some contention by respondent that these tubes were high vacuum tubes operating with a pure electron discharge, we believe it is clear from the record that this was not the case. The best evidence of this is to be found in Langmuir's own notebook under date of March 21, 1913, as follows:

> "Now what I intend to do is to construct an audion which will operate entirely and exclusively on the electron discharge. I shall attempt to get the vacuum so good that positive ions are present in negligible amounts." (Plff's. Ex. 131, p. 34, Interf. Ex. U.)

This is a perfectly clear statement of conception of the only possible invention here in issue, but it is, of course, much too late to be of any avail to Langmuir since this had been done in 1912 by both DeForest and Arnold (this brief, pp. 22 to 28).

It is for this reason that we hear so much in this record of Langmuir's earlier experiments during August and November, 1912. But it seems to us that Judge MORRIS has properly characterized the earlier experiments, when he said so accurately in his opinion (Rec., Vol. III, p. 1961):

> "Langmuir made many experiments over a long period of time. Those that were first made were, however, for the purpose of discovering abstract principles and not for the purpose of arriving at practical results. He made discoveries but he did not immediately, or for some time, perceive that they had any practical use. Moreover, the discoveries to which his experiments led him, so far as we are here concerned, were those already made by Lilienfeld and others. * * * But the disclosures of the prior art reveal that Langmuir, great and renowned physicist that he is justly conceded to be, was, in this instance, traveling, all unknown to him, over a field already well explored."

We submit that not only was Langmuir, in his earlier experiments, traveling, all unknown to him, over already well-explored fields, but, in his only practical application of the principle of pure electronic discharge as well, he was completely anticipated by these other workers in the art.

He cannot patent the principle and he is anticipated in his only practical application of that principle, even if such application were not otherwise unpatentable.

CONCLUSION.

Upon the foregoing, we contend that the decree of the Court below should be reversed and the bill of complaint dismissed.

Respectfully submitted,

JOHN F. NEARY,
RAMSAY HOGUET,
MARTIN T. FISHER,
Of Counsel for
The Chemical Foundation, Inc.,
Radiological Society of North America,
Radiological Research Institute, Inc.,
Federal Telegraph Company,
As Amici Curiae.

FILE COPY

JAN 8
CHARLES ELMORE

IN THE

SUPREME COURT OF THE UNITED STATES

OCTOBER TERM, 1930

No. 630

DEFOREST RADIO COMPANY
Petitioner

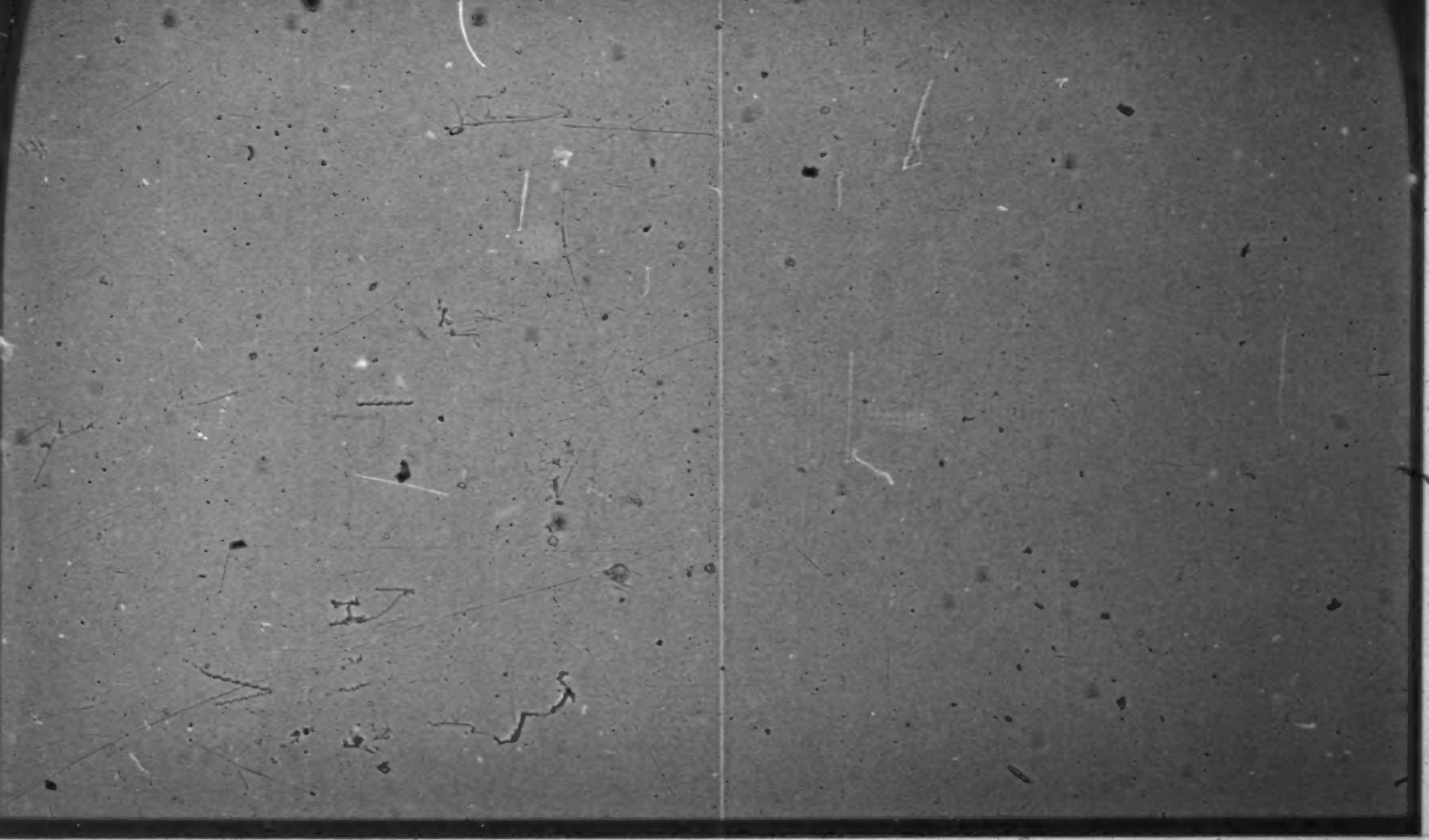
v.

GENERAL ELECTRIC COMPANY
Respondent

OPINIONS OF JUDGE MORRIS AND JUDGE WOOLLEY

THOMAS G. HAIGHT
SAMUEL E. DARBY, JR.
Counsel for Petitioner

APPEAL PRINTING CO., 33 THAMES ST., NEW YORK CITY



INDEX

PAGE

The Opinion of Judge Morris (District Court of Delaware) 1

The Opinion of Judge Woolley (dissenting from present majority decision of the Third Circuit Court of Appeals) 30

IN THE

District Court of the United States

FOR THE DISTRICT OF DELAWARE.

GENERAL ELECTRIC COMPANY, *Plaintiff,* v. DEFOREST RADIO COMPANY, *Defendant.*	Nos. 589 and 598. In Equity.

The Opinion of Judge Morris.*

(23 Fed. [2nd] 698)

These two suits of General Electric Company against DeForest Radio Company were tried together. In the first suit all the claims of patent No. 1,558,436, granted to Irving Langmuir, assignor to the plaintiff, October 20, 1925, for "electrical discharge apparatus and process of preparing and using the same" upon an application filed October 16, 1913, and renewed March 14, 1916, are in issue. It is known as the high vacuum tube patent. Infringement is conceded if the claims are valid. Validity is denied for want of invention and novelty and because of prior knowledge and use, for double patenting and upon the ground that Harold D. Arnold, not Langmuir, was the first inventor.

The specification, claims and testimony are so interwoven with scientific theories, more or less abstruse, that

* The opinion of Judge Morris dealt with four Langmuir patents. We are here concerned only with Langmuir patent No. 1,558,436. We have, therefore, only printed that portion of the opinion dealing with this patent.

it is somewhat difficult to isolate and keep separate from the principles of physics involved Langmuir's conception and idea of means. Yet an analysis of the Langmuir device and its element[illegible] discloses that, apart from its functioning and result[illegible] is nothing more nor less than a Fleming valve or D[illegible] audion, for example, in which a higher vacuum, m[illegible]inable during operation, exists. How much hi[illegible] the vacuum must be to bring the tube within the pate[illegible] is not definitely fixed in terms of pressure. The specification states merely that "the evacuation of the device should be preferably carried to a pressure as low as a few hundredths of a micron, or even lower, but no definite limits can be assigned." A micron is a pressure equal to a millionth of a meter or a thousandth of a millimeter of mercury. It corresponds to a barometer reading of that value. The normal barometer reading in the open air is about 760 millimeters. The justification for the failure to assign definite pressure limits is that the invention "comprises devices in which the electrical current is carried by negative charges called electrons, emanating from the cathode, independently of gaseous ionization"—a device in which the residual gases play no part in the operation. The results desired to be obtained are stability and reproducibility of operation and increase of power. The production of these results by the specified manner of functioning is dependent not on the degree of vacuum alone, but upon four coordinating variables—geometry or relation of parts of the tube, temperature of cathode, voltage of anode and degree of vacuum. This fact makes it apparently unavoidable that the claims be functional in form. But they must, of course, be construed to cover the thing. Walker on Patents §163. Claim 26 is comparatively simple. It is:

"A discharge device comprising a sealed off envelope and electrodes therein, the envelope being shaped and the electrodes located so that the energy of the discharge is delivered mainly upon one or more of the electrodes, the inner wall of the envelope and electrodes being so free from occluded gas and the pressure in the tube being sufficiently low, with respect to the spacing of the electrodes and the energy of the discharge, so that the device is capable of passing a sustained discharge of one tenth of a milliampere at forty volts, without developing any substantial positive ionization effects."

The Fleming and DeForest tubes are "discharge devices comprising a sealed off envelope and electrodes therein, the envelope being shaped and the electrodes located so that the energy of the discharge is delivered mainly upon one or more of the electrodes." The next clause of the claim—"the inner wall of the envelope and electrodes being so free from occluded gas and the pressure in the tube being sufficiently low, with respect to the spacing of the electrodes and the energy of the discharge"—has to do with the manner and degree of evacuation. Underlying this clause are these facts: The glass wall and the electrodes harbour large volumes of occluded gases. Heat is necessary to expel these gases so they may be removed by the pump. If not removed before the tube is sealed off the heat occurring during the operation of the tube expels them, destroying in large degree the vacuum. "The spacing of the electrodes"—one illustration of the geometry of the tube—is a factor because the permissible gas pressure in the tube increases with the proximity of the electrodes to each other. This varying relation is due to the fact that the opportunity for the electrons to collide with gas molecules varies with the length of the path the electrons have to travel. "The energy of the discharge"

may be interpreted in terms of power which is the product of the current values and the voltage. The unit of current flow is the ampere or the current which flows at a pressure of one volt through a closed circuit having a resistence of one ohm. The power of a circuit having a pressure of one volt and a current of one ampere is one watt. The power output of the device of claim 26 is .004 of a watt or 4 milliwatts. And increase of energy means an increase in the number and velocity of the electrons passing from cathode to anode and consequently an increase in the number and effect of collisions of electrons with gas molecules. It follows, of course, that if the maximum voltage at which a given tube will function without ionization is increased ionization will occur and the tube fail to function in the manner specified in the patent. "Ionization," by which is meant the conversion of atoms or molecules into ions, is explained by the "Electron Theory." By this all atoms known to chemistry are deemed to be made up of a nucleus endowed with a permanent positive electrical charge around which one or more electrons, each of which has mass or weight and carries, or is, a natural unit of electricity, revolve at inconceivably great speeds in regular orbits in somewhat the same manner as that in which the planets of our solar system revolve about the sun. According to this hypothesis the chief difference between the chemical atoms lies in the number and arrangement of their electrons. Under normal conditions the electrons are maintained within their atoms and in their orbits by the attractive force of the positive nucleus which, electrically, exactly balances and neutralizes the negative charge of the electrons of the atom. Consequently every atom having its normal complement of electrons exhibits no electrical effects. If, however, by impact, or otherwise, an atom loses an electron and becomes

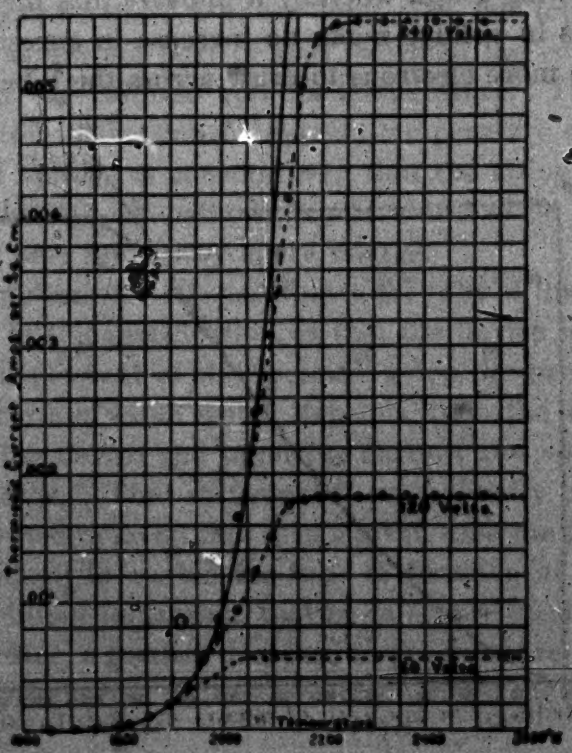
an ion it is thrown out of electrical balance. The positively charged nucleus predominates and exhibits a unit positive charge. In thermionic tubes ions are created by the impact upon the gas atoms or molecules of some of the myriads of electrons constituting the current flowing from the hot cathode to the cold anode—the Edison Effect. See Westinghouse Elec. & Mfg. Co. *v.* DeForest Radio Tel. & Tel. Co., 21 Fed, (2d) 918. To dislodge an electron from its atom the colliding electron must have sufficient momentum. The velocity required for this momentum is given to the electrons mainly by the pull or attractive force of the positively charged anode. The strength of the pull increases, other conditions being stable, with the anode voltage. For the gases with which we are here concerned 15 to 25 or 30 volts constitute the ionizing voltages.

When substantial numbers of atoms or molecules are being converted into positive ions by the electron stream the "ionization effects" forbidden by claim 26 occur. One effect of ionization is an increase in the current across the tube over the value it would have at the same voltage in the particular tube were the vacuum sufficiently high to prevent ionization. Such increase is due to two facts. First, the electrons, being negative charges of electricity, tend in the absence of a countervailing force, violently to repel one another and thus to diminish the number, and so, the value of the current, passing to the anode. Positive ions in the field constitute a countervailing force and consequently expedite the flow of the electrons to the anode. Second, the positively charged ions are drawn with great force to the cathode, the negative electrode, bombard it and thus increase its temperature. As the electron emissivity of the cathode increases with its temperature the ion bombardment of the cathode serves to

increase the supply of electrons and consequently the current passing to the anode. This bombardment is so severe that, if continued, it destroys the filamentary cathode. Another effect to which substantial ionization usually gives rise is a blue glow in the tube. This, as I understand it, is accounted for upon the hypothesis that as the electrons are shifted in the atom, by impact of the electrons, from one orbit to another at prodigious speeds they produce waves or vibrations in the ether which constitute light. The ultimate effect or result of ionization is an unstable, non-reproducible and, in a measure, non-controllable current. As it is necessary, in order to prevent the destruction of the cathode and obtain a stable current, to operate gassy tubes below ionization, their power output—the product of current and voltage—was limited. These constitute obvious defects.

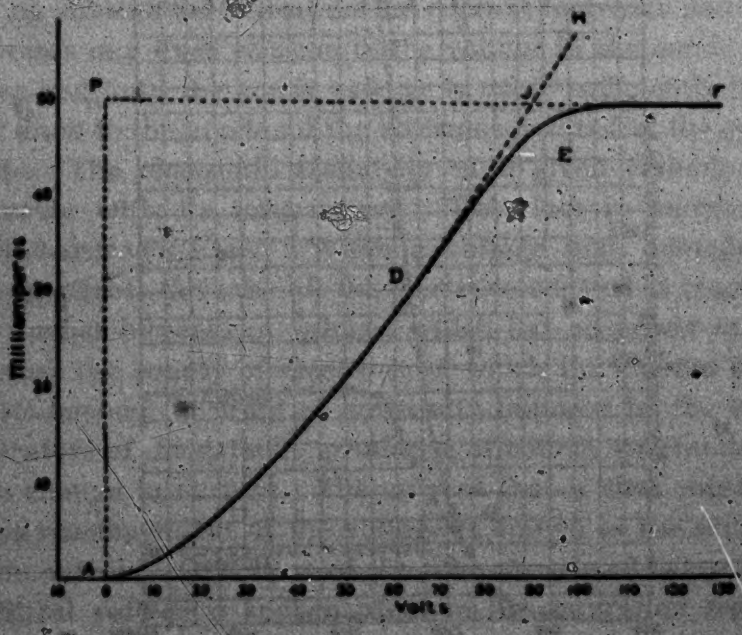
These defects are not present in the tube of the patent. It operates without substantial ionization. When there is no substantial ionization the current increases and decreases in a fixed relation to the voltage of the anode unless and until the anode voltage is made sufficiently high to draw to the anode all the electrons emitted at the cathode. The electronic emissivity of a given cathode increases with its temperature. This fact is known as "Richardson's Law." When a voltage high enough to carry across the tube all the electrons emitted is reached a further increase of voltage, which has no power to increase the supply of electrons of which the current consists beyond the limit of emissivity imposed by the temperature of the cathode, produces, of course, substantially no change in current. The current that is thus substantially independent of the voltage is known as the saturation current. Operation of the tube above and below this critical voltage is spoken of as in the saturation region

and below saturation respectively. If a tube is operating below saturation an increase of the electron supply by an increase of cathode temperature, but with no increase in voltage, produces no marked change in the current. Decreasing the electrons emitted by the cathode by decreasing the cathode temperature is likewise without effect upon the current, provided, of course, that the decrease in the supply of electrons is limited to the electrons emitted in excess of those pulled across the tube by the given voltage. The fact that if the anode voltage remains stable the current can not be increased by an increase of the cathode temperature, beyond that required to supply the electrons capable of being pulled across the tube at the given voltage is illustrated by the "flat top temperature curve" on the following graph.



The reason that the current does not increase beyond a certain point dependent upon anode voltage with the increase of the temperature of the cathode is that the electrons, all being negatively charged, exert powerful repelling forces on one another. When this force of repulsion equalizes the pull or effect of the voltage on the anode, the anode is without power to draw to itself a greater number of electrons. The current-limiting effect of the electric field of the electrons on one another is known as the "space charge effect." It is space charge which produces the flat top of the temperature emission curve in the foregoing graph.

When the temperature of a cathode is fixed and constant and the voltage is increased the limitation upon the electrons limits the current. This is illustrated by the following graph whereby it appears that the last few increases in voltage make no increase in current—there being no more electrons to draw across the tube.



The curve of this graph, which when plotted on logarithmic paper appears, up to the point approaching saturation, as a straight line, discloses a relation existing between current and voltage. That relation is expressed in the specification thus:

> "In most devices of simple construction which embody my invention, the discharge current passing through a given space with the cathode at a sufficiently high temperature with respect to the voltages employed, varies directly with the 3/2 power [square root of the cube] of the impressed voltages."

"A" to "D" of the curve on the current-voltage chart, in which the temperature is constant, is the space charge part or that in which the current is limited by anode voltage and follows the 3/2 power law. The flat top represents the saturation part or that in which the current is limited by the cathode and its temperature. The converse is true in the first or current-temperature chart in which the voltage is constant. In that the rising part is the part limited by cathode temperature while the flat top is the part limited by space charge.

Another characteristic peculiar to the tube of the patent, as stated in the specification, is that the device is "practically independent of the pressure when the pressure is below a certain value which depends upon the size and shape of the device and upon the current and voltage of the discharge." That statement is undoubtedly true if it be interpreted to mean that if in a given tube the pressure is low enough to enable the tube to function at a given voltage without ionization, that is, as a pure electron discharge device, a further decrease in the pressure will not affect the discharge. It is likewise true that if the pressure

is less than that required for a given voltage in a given tube it may be increased up to the pressure immediately below that at which substantial ionization would occur at the given voltage without affecting the discharge. The discharge, however, is in no sense independent of the pressure if the maximum voltage at which a given tube will function without ionization is increased, for ionization would instantly occur and the tube fail to function in the manner specified in the patent. In such instance a decrease in pressure simultaneously with the increase in voltage would be necessary to avoid ionization. In its simplest aspect this is due, of course, to the fact that if ionization is to be avoided above ionization voltages collisions must be avoided between electrons and gas molecules and that the number of collisions in a given tube, dependent upon the relative density of the two, is increased, the pressure being stable, by an increase in the number of electrons pulled to the anode by the increased voltage.

These scientific explanations, arising mainly out of the electron theory, of the functioning of the high vacuum tube change not at all the fact that it differs structurally from the Fleming valve and DeForest audion only in the degree of vacuum maintainable during operation. This was expressly conceded during the pendency of the application in the Patent Office. The fundamental questions here in issue are not changed and their solutions are, I think, but little affected by the theories by which the functioning of the high vacuum tube is accounted for. If it was not known to those skilled in the art how to produce, in a Fleming or DeForest structure, for example, a vacuum sufficiently high to enable the tube to function above ionization voltages without substantial ionization and Langmuir solved the problem and made the necessary

disclosure of its solution in his patent, manifestly he would be entitled to a patent for his disclosed method and device as a reward quite apart from his knowledge or lack of it with respect to scientific principles or laws of physics explaining the functioning brought about by the high vacuum. Moreover, independently of whether or not invention was necessary to create a vacuum of the required degree, Langmuir would be entitled, I take it, to a patent for his device regardless of his ability or inability to explain its functioning in principles of physics, if he was the first to appreciate that a high vacuum maintainable during operation in a Fleming or DeForest structure, for example, would constitute means whereby the results produced by the high vacuum tube could be accomplished, provided, of course, he reduced to practice with reasonable diligence the device of his mind.

Upon the question whether the claims for the process of making the high vacuum tube or those for the tube itself, which because of its stability, reproducibility and power has made possible radio broadcasting, modern radio reception and long distance telephony, involve novelty and invention the parties differ widely. The plaintiff asserts, with apparent confidence, that the patent is for invention of a high order—equal to or greater than that of DeForest for the three electrode tube. The defendant, with equal confidence, finds not only all that Langmuir did but all that he discloses with respect to the principles in accordance with which the device functions spread upon the records of the prior art. Since the Fleming valve and the DeForest audion were old and the structure of the tube of the patent differs from these only in the degree of vacuum maintainable during operation the first crucial question is whether claims 30, 31

and 32, directed to the process of making tubes having a vacuum of the required degree are valid. Claim 31 is:

> "In the process of producing a hot cathode discharge device, treating the interior surface of the envelope and the operating parts to liberate therefrom occluded gas, and removing from the envelope gas liberated by said treatment and free gas originally contained therein, continuing these operations until the occluded and original free gas is so thoroughly removed as to enable the finished sealed-off device to operate below saturation in a stable and reproducible manner at a voltage above fifty volts and with a current greater than one milliampere and with the energy of the discharge delivered mainly at one or more anodes."

To find wherein, if at all, this and the other process claims go beyond the discoveries and ideas of others, beyond the use of wise judgment in selecting and combining those discoveries and ideas, or beyond mechanical skill in applying them to practical results, the specification and the prior art must be examined. The specification states:

> "For the evacuation of the device the glass walls of the tube are carefully heated to as high a temperature as the glass will stand without softening and in general the most approved methods of incandescent lamp exhaust are used. The evacuation of the tube preferably while still heated is carried out by means of a suitable evacuating means, for example, a Gaede molecular pump, which removes vapors as well as gases. Chemical evacuating means such as electrically vaporized calcium or magnesium may also be used. Either before or during the evacuation the anodes may be heated, especially when the anodes are to be run at elevated temperature during the normal operation of the device. In this case the temperature is prefer-

ably carried close to brilliant incandescence. In the case of the structure shown in Fig. 1, the heating may take place by passing an electrical current through the wire 12. The heating, especially of solid anodes such as shown in Figure 2, may take place in a suitable vacuum furnace, the temperature preferably being raised to 2,500° C. or even higher. Bombardment is a very effective means of removing occluded gas from anodes."

The steps and precautions requisite to successfully evacuate by bombardment are then described after which the specification adds:

"After the metal has been freed from occluded gas reabsorption of gas will not readily take place even though it is exposed to the air or other gases. For example, anodes thus treated may be removed to other apparatus which then may be evacuated with less electron bombardment of the anode or anodes. * * * It is also true that when the anode has been carefully freed from gas residual free gas, even if present in a sufficient amount to cause some gas ionization when the apparatus is first started, does little harm, as it is quickly removed by the gas clean-up effect when the device is operated."

The prior art, however, as I understand it, discloses that long before the earliest date claimed for Langmuir it was known not only that large quantities of gas are occluded in the glass walls and electrodes of an electrical discharge device and that unless removed before or during evacuation the gas will be driven out by the heat of operation and thus detrimentally increase the pressure of the vacuum, but also that the occluded gases could be removed and the vacuum created and maintained by the very steps prescribed by Langmuir for removing the occluded and free gases of his device. In May, 1896, the

"American Electrician" published an article by Thomas Duncan in which he said:

> "If an incandescent lamp be exhausted until no air can be seen escaping through the valves of the pump, and the filament then incandesced, considerable quantities of air will be expelled at each operation of the pump, thereby showing that this air has been occluded in the pores of the carbon filament, and could not have been gotten rid of without heating the filament and driving the air out into the vacuous space surrounding it.
>
> "This heating also assists in drawing off the air which clings or adheres against the glass upon the inside of the bulb. If the electrodes are made from aluminum or other porous metal, the secondary terminals from a spark coil can be applied to them, and set in operation in a similar manner to that in which the tube is to be used afterwards. This can not help but be a ready and satisfactory means of eliminating the air occluded within the electrodes."

A résumé of Incandescent Electric Lamp Exhausting by S. E. Doane, published in the "Electrical World and Engineer" of May 21, 1904, says:

> "The exhausting of incandescent electric lamps has developed into a highly specialized branch of the lamp manufacture. * * * The completed lamp must not only be free from gases and vapors, but must also have had those parts capable of giving off gases and vapors, thoroughly freed from them. The only way we knew to accomplish this was to highly heat everything we wished to free from gas. We had three things to heat: the glass, the filaments and the joints between filaments and leading-in wires.
>
> "The glass was heated by an asbestos cone-shaped hood painted black on the inside. The heat from

the lighted lamp furnished all the heat necessary. The lamps could be heated hot enough to cause the bulb to collapse if the hoods were made too thick. The filaments were also heated sufficiently by the current, * * *."

Dwyer, in his patent No. 596,694, granted January 4, 1898, for a process of producing high vacuums in incandescent electric lamps or similar receptacles during their manufacture recites that in the past such lamps have been exhausted by mechanical pumps, "by chemical processes involving the displacement or absorption of the gases contained in the lamp, or by combinations of these processes." He says that a partial vacuum is readily obtained by a good mechanical or mercurial pump but that complete exhaustion by this means alone is not possible. He then adds:

> "To carry the vacuum still higher, it has been a common practice to heat the lamp-bulb by either an external source of heat, such as a gas-flame, or by an electric current passed through the lamp-filament, or by both of these means combined, so as to expand the gases in the lamp, and also to drive off from the lamp-filament itself and its supports, more particularly the joint between the leading-in wires and the filament, which joint is usually made of some form of hydrocarbon paste, gases occluded therein, while continuing the pumping operation."

Soddy, in his patent No. 859,021 of July 2, 1907, for the employment of certain reagents in the process of producing high vacuum, declares:

> "In the production of high vacua not only has the air to be removed but also the gases occluded or condensed on the walls of the vessel being exhausted and on the contained electrodes or fila-

ments or other contents of the said vessel, which condensed gases are given up slowly after exhaustion and if not removed during the exhaustion cause the vacuum to deteriorate. * * *

"The heating and expelling of the condensed and occluded gases may be effected in any usual, or suitable, manner of expelling condensed and occluded gases from the walls and contents of vessels being exhausted. The usual manner of effecting such an operation is to heat the vessel while it and its contents are subjected to the same treatment as they are subjected to in after use. In incandescent electric lamps for example an electric current is passed through the filament, and in X-ray bulbs an electric discharge is passed between the electrodes during the continuation of the exhaustion."

Many other references disclose the baking of the walls of the envelope of a discharge device, the heating of the electrodes, incandescing the filament and electron bombardment of metallic electrodes to expel occluded gases. The gas clean-up effect was likewise old at the time Langmuir began his operations. One instance of its disclosure is in patent to Thatcher No. 1,028,636, granted June 4, 1912, application for which was filed March 30, 1910, for method of exhausting vessels, in which it is said in part:

"I institute the intensive incandescence of the filament proper, that is I bring the current voltage up to a sufficient intensity to produce the blue haze phenomenon, and maintain the same until the blue haze disappears and the desired almost perfect vacuum is attained; * * *"

Dr. E. Leon Chaffee testified (R. Vol. 1, p. 159):

"It has long been known that the existence of this blue glow improves the vacuum, probably by bom-

barding the walls with gas ions and consequently causing them to stick to the glass walls. * * *."

These steps of the prior art are the identical steps disclosed by Langmuir. Nor are his disclosures with respect to how these steps are to be employed any more ample or complete with the possible exception of heating by bombardment. But bombardment has no saving power for the claims are not restricted to heating by bombardment. They are broad enough to include any method of "treating the interior surface of the envelope and the operating parts to liberate therefrom occluded gas, and removing from the envelope gas liberated by said treatment and free gas originally contained therein." The plaintiff, however, places some reliance upon the clause in the claims directing continuance of the steps until the desired vacuum is attained and cites Badische *v.* Kalle, 104 Fed. 802. But in that case those skilled in the art were of the opinion that a more prolonged or intense application of the old steps would not accomplish the desired result. Such is not the evidence here as I understand it. Moreover, the tools of the evacuating art were constantly improving. In the early days of the incandescent lamp art manufacturers used the Sprengle pump to obtain their vacua. It gave way to the Geissler pump which, in its turn was superseded or supplemented by chemical evacuating processes. It is, I think, not denied that these old pumps and at least some of the chemical processes left in the tube mercury or other vapors having a pressure too high for the tube of the patent. But if Langmuir makes in his specification any disclosure of steps or means to avoid that result it is by the use of the new, improved Gaede molecular pump. That pump is highly efficient and, when properly used, leaves no free

gas or vapor that will prevent the functioning of a thermionic tube above ionization voltages without substantial ionization. But Langmuir is entitled to no credit for that. I think the process claims are invalid.

This conclusion carries with it as a necessary corollary that the device itself, apart from its functioning and use, is lacking in patentable novelty. The inventive quality of the device claims, if any they have, must consequently reside in the discovery of a new principle that thermionic discharges above ionization voltages can be produced without substantial ionization if the vacuum be sufficiently high and the disclosure that the device of the claims constitutes suitable means for putting the principle into practice to obtain useful results, or, in the application of that principle, if known, to a useful purpose—in the realization that the instability, non-reproducibility and lower power output of the gassy tube was due to inadequate vacuum and the conception of a tube with a higher vacuum as a means whereby stability, reproducibility and high power output in thermionic devices might be had. That Langmuir was not the first to discover that a pure electron discharge, a discharge without substantial ionization, can be produced in a thermionic device if the vacuum is sufficiently high was indicated by Richardson's Law, evolved and formulated about 1903. If, perchance, that law was not universally accepted by physicists as being operative in high vacua, as was suggested by Soddy, Pring, Parker and some others, the publications of Lilienfeld in 1910 were clear, complete and specific upon this point. In fact, Langmuir admits (I. R., p. 1378) that Lilienfeld had thermionic discharges above ionization voltages "substantially free from the effects of positive ionization." Moreover, if a thermionic discharge is unaccompanied by substantial ionization all the asserted "ear-

marks" or characteristics of plaintiff's device are present for they are but incidents flowing from a sufficiently high vacuum for the voltages employed, or, otherwise expressed, from an absence of ionization. These characteristics are, or include, (1) regularity and reproducibility of operation, (2) 3/2 power relation of current to voltage, (3) no blue glow or other visible evidence of discharge, (4) cathode not heated by the discharge, (5) current limited by space-charge effect and (6) discharge independent of pressure in vacuum below certain pressure in the sense hereinbefore stated. As I understand the evidence these "earmarks" are likewise characteristics of the Fleming valve and original DeForest audion when operated at non-ionizing voltages. It thus seems obvious that the merit of the invention, if any, must lie in the realization that the known pure electron discharge to be had in a high vacuum would overcome the special difficulties and limitations of thermionic discharge devices. Whether this realization and the increase of vacuum in structures of the Fleming and DeForest type was a probable natural development of the art or one requiring inventive skill is, like the question of the presence or absence of invention in other cases, not without some difficulty.

One class of evidence which often carries much weight is the necessity for a series of experiments before the result can be arrived at. Such evidence raises a strong inference that the result was not obvious and constitutes a real addition to public knowledge. But for such experiments to be of much value the patentee must have started his experiments with knowledge of the state of the art or his experiments may have succeeded in enabling him to redisclose only what was already known. Langmuir made many experiments over a long period of time. Those that were first made were, however, for the purpose of dis-

covering abstract principles and not for the purpose of arriving at practical results. He made discoveries but he did not immediately, or for some time, perceive that they had any practical use. Moreover, the discoveries to which his experiments led him, so far as we are here concerned, were those already made by Lilienfeld and others. Great credit, bearing upon the issue of invention, is claimed by the plaintiff for Langmuir for discovering from his experiments that electrons will boil out of a hot cathode in a high vacuum, that in a high vacuum the current varies with the 3/2 power of the voltage and other characteristics or incidents of a discharge in a high vacuum without substantial ionization. But disclosures of the prior art reveal that Langmuir, great and renowned physicist that he is justly conceded to be, was, in this instance, travelling, all unknown to him, over a field already well explored. Fleming, the inventor of the Fleming valve, published in the "Scientific American Supplement" for January 20, 1906, an article on the electric conductivity of a vacuum, disclosing not only that electrons are emitted by a hot cathode in a high vacuum but also "that a high vacuum may be a very good conductor, provided that the negative electrode is rendered incandescent. This shows that the obstruction which a high vacuum offers to the passage of electricity is not due to the mere reduction of the matter in the space (that is, to the rarefaction of the gas), but is, in some way or other, largely dependent upon the temperature of the electrodes; the resistance to the passage of electricity through a vacuum can be rendered very small by intensely heating the negative electrode," thus revealing that a current could be had passing from cathode to anode. In addition, Fleming stated: "If we take measurements of the current passing through the vacuum when the negative electrode is an

incandescent carbon filament and the other a cold metal plate, and, at the same time, measure the difference of potential between the electrodes, we find that the conductivity, as measured by the ratio of current to voltage, is not constant, but varies with the electromotive force." Furthermore, that Fleming knew the difference between a high and low vacuum is made manifest by his statement: "The vacuum is said to be low when the original normal air pressure in it is reduced to one-thousandth atmosphere, or it may be only to one three-hundredth. It is said to be high when it is reduced to one hundred-millionth of an atmosphere." It is true, as shown by the Fleming curve sheet, that Fleming did not employ in his valve a high vacuum but it is also true that Langmuir, Q212, conceded "There is no advantage in the device of the character of the Fleming valve to go to pressures of less than 50 microns." Both C. D. Child, in an article in the "Physical Review," Vol. 32 (1911), and Lilienfeld, in an article entitled "Conduction of Electricity in Extreme Vacuum," published in "Annalen der Physik," Vol. 32 (1910), disclosed that with the aid of certain simplifying assumptions, such as the ignoring of the initial velocity with which the electrons are boiled out of the cathode, the discharge current varies in accordance with the three-half power of the voltage. This is conclusive evidence, as I understand it, that in a high vacuum the current is under control, stable and reproducible and, since high voltages were employed, that high power levels may be attained by the employment of a high vacuum. "Space charge effect" was, likewise, but a rediscovery. This is made certain by an article by Lilienfeld in "Physikalische Zeitschrift" 1908 in reply to an article by Soddy dealing with the Wehnelt cathode in high vacuum in which Lilienfeld said:—

"* * * it is not exclusively the electrons emitted from the exide cathode which, as was often assumed, determined the discharge in high vacua, but that the discharge depends essentially on a second factor. I pointed out more specifically in my second paper this view, that in consequence of the absence of the last traces of gas the number (volume density) of the negative electrons supplying the current becomes great in comparison with the number of gas molecules per unit volume, so that therefore the tendency exists for the formation of the greatest possible negative space charge—which opposes the current transport by the negative electrons.

"The higher the vacuum, the greater the current density, the more prominent this new kind of discharge becomes * * *"

That the discharge in high vacuum devices is practically independent of the pressure when the pressure is below a certain value was discovered by Langmuir after Lilienfeld had made the disclosure in his article of 1910, where he said:

"* * * from a certain maximum value of the gas density downwards the number of positive charges formed per negative charge, *i. e.*, per negative electron is independent of the gas density.

"Since we usually regard positive charges as originating from molecules (or atoms) we can put this result in the following form: the number of positive charges per molecule increases continually with diminishing gas density in the region of validity of the function K which is independent of the gas density provided other conditions (the potential gradient) are kept constant."

In view of these publications it seems to me that the only permissible inference to be drawn from Langmuir's ex-

periments is not that they constitute evidence of invention but is rather that Langmuir was not abreast of the developments in this particular art when he made his experiments.

Other evidence bearing upon the issue of invention is the great utility of the high vacuum tube. But in 1912 the radio art was young. Fleming did not need for his purposes, as Langmuir testified, a higher vacuum than that employed by him. The DeForest audion was not in wide use. Langmuir did not see one until 1913. Under such circumstances it would be difficult to say that the high vacuum tube satisfied a long felt want or produced results long sought or that the evidence of utility is here indicative of anything more than a proper natural development of the art. Moreover, the fact that falls but little short of a demonstration that the employment of the known pure electron discharge above ionization voltages in tubes of the DeForest type was but the availment of those skilled in the art of the store of knowledge that had been accumulated and lay ready at hand is that when Arnold, who had had long experience with electrical discharges in high vacuum, was shown a DeForest audion for the first time on November 1, 1912, and saw it in operation he immediately realized and said, in effect, that by increasing the vacuum the discharge would be sufficiently stable and at adequate power levels to enable the tube to be employed as a relay device in trans-continental telephony. While not unmindful that invention may sometimes be the result of an instantaneous happy thought, yet the state of the art is strongly confirmative of Arnold's own view at the time that the improvement suggested by him was obvious to one skilled in the art. The act of Arnold turns the scale so overwhelmingly that it lies athwart a finding of invention.

The patent is likewise invalid, in my opinion, because of prior knowledge and use by DeForest. The specification states: "Ordinarily the gas ionization in the audion begins to be important somewhere between 20 and 30 volts." That, as I understand it, means that at this voltage the current becomes affected by positive ionization and the tube ceases to function as a pure electron discharge device. Yet, prior to August, 1912, the Federal Telegraph Company of California, by which DeForest was then employed, used a B battery of 36 cells, another of 45 cells, or 54 and 67½ volts respectively, with the audion. When used as an amplifier the amplification increases with the voltage. The testimony of Langmuir, XQs761-767, as I understand it, makes it clear that this voltage was employed for amplifying purposes and so with a discharge current substantially unaffected by ionization. That DeForest, though not skilled in the art of evacuating his device, knew the effect thereon of an increased vacuum, though he was very probably unaware of the extent to which it could be carried, is disclosed by his letters of July 26, 1912, and August 14, 1912, to the McCandless Company, the manufacturer of audions for the Federal Telegraph Company. The first letter is:

> "Out of the last lot of 24 audion bulbs which you manufactured for us there are only 4 that came up to proper sensitiveness test. Apparently the vacuum in the other bulbs is too low, because in these latter bulbs we notice that the blue arc or cathode beam starts suddenly at 15 or 20 volts, under which condition the bulb is not sensitive."

The other letter reads:

> "We took two of the poorest of the discarded 20 to a San Francisco glass-blower, unknown to fame,

and had him exhaust same to as high a vacuum as his pumps would take. These re-exhausted bulbs now show a sensitiveness equal to those of the first four which proves exclusively that our contention is correct. For the work which we demand from these bulbs they are not sufficiently sensitive and we would be glad therefore if you will re-exhaust them. You certainly should be able to put them in as good condition as the aforesaid San Francisco glass-blower."

The testimony discloses that the glass-blower referred to heated the tubes under an asbestos hood almost to the collapsing point of the tube while they were being exhausted. The references of the prior art which reveal that a lamp may be made to collapse by heating under an asbestos hood leave no room to doubt this testimony. Such heat was sufficient to heat to a certain degree the metal electrodes as well as the walls of the tube, thereby driving off from the electrodes as well as the walls some of the gases occluded therein. The energy of the discharge of the DeForest tube was low. The bombardment was probably not adequate to heat the anode to a temperature even approximating that to which it was raised by the Bunsen burner under the asbestos hood. Consequently, little, if any, occluded gas would escape from the anode and the gas cleanup effect probably tended to improve the vacuum more than it was caused to deteriorate by the molecules of gas that escaped from the anode. The tubes were thus enabled to function substantially above ionization voltages without substantial ionization.

Upon the issue of priority, too, I think the plaintiff must fail. In the contest in the Patent Office between Arnold and Langmuir upon this issue the Examiner of Interferences awarded priority to Langmuir. The Examiners-in-Chief arrived at the same conclusion but

for reasons conflicting with those of the Examiner of Interferences. The Commissioner of Patents awarded priority to Arnold. The Court of Appeals of the District of Columbia decided in favor of Langmuir for the reasons stated by the Examiner of Interferences and the Board of Examiners-in-Chief. I am in accord with neither of the divergent views expressed by the Examiner of Interferences and the Board of Examiners-in-Chief but, generally, with the reasoning and conclusion of the Commissioner of Patents. The defendant asserts that Arnold is entitled to the date of November 1, 1912. Upon that date Arnold, who because of his training and experience in the matter of electrical discharges in vacuum and upon the recommendation of Dr. Robert A. Millikan, had been theretofore employed by Western Electric Company to aid in making possible trans-continental telephone service at the opening of the San Francisco Exposition, was shown by Doctors Jewett and Colpitts a DeForest tube that had been brought by DeForest to the Western Electric Company a day or so before. Arnold examined the audion and tested its performance as a repeater of speech currents. It functioned well with weak currents but choked, distorted the speech and blue hazed when increased plate voltage or loud speech currents were applied. Though Arnold had been engaged in perfecting a different device of his own to be employed for telephone relay purposes, he instantly saw that the performance of the tube which made it too unstable in its existing state for a telephone repeater was due to ionization and that this could be removed by increasing the vacuum. This he then disclosed to Colpitts and Jewett. He also understood and then explained to Colpitts that the hot cathode would emit electrons in the high vacuum, that they would be subject to the space charge effect and that it would require

high plate potentials to obtain the desired electron flow from cathode to anode. Corroboration of the oral testimony of Arnold, Colpitts and Jewett, if needed, is to be found in the fact that every act of the Telephone Company from that time on is consistent only with the intended use of the audion made more rugged and with a higher vacuum in its trans-continental service. Arnold's conception of the invention, consisting in the full performance of the mental part of the inventive act, was complete. Nothing remained to be done but to give the device practical embodiment with reasonable diligence. If, in view of the fact that those skilled in the evacuating art knew how to reduce to physical form Arnold's mental conception, a physical reduction of his conception to practice was necessary, and I think it was not, McCormick Harvester Mach. Co. *v.* Minneapolis Harvester Works, 42 Fed. 152, 155. Otto *v.* Linford, 46 L. T. (N. S.) 35, this requirement was performed by Arnold with reasonable diligence, thus giving to him an effective date of November 1, 1912. He obtained, knowingly, in that month with audion 7-A a current of 3 milliamperes at 80 volts without substantial ionization. Again, Arnold met the requirements of reduction to practice in April and May of 1913. In the tubes of these experiments 250 volts were impressed upon the plate without ionization effect. The tubes used in Philadelphia in the fall of 1913 functioned well for many hours, one as long as 267 hours as commercial repeaters. The fact that the output energy of one of these tubes was less than that of the usual, original DeForest tube does not negative its being a tube of the patent, for the output energy of claim 26 is likewise less than the output energy of the usual, old DeForest tube. Moreover, it seems to me that other claims of the patent, for example 11, which was an original claim, differs from

26 in the same way and only in the same way that claim 26 differs from the original DeForest device.

Langmuir began his experiments in August of 1912. He now asserts and the defendant denies that he then obtained a pure electron discharge substantially unaffected by positive ionization but concedes, XQ380, that though he now knows that he did then obtain such a discharge he did not know it then. This lack of contemporaneous knowledge denies to his August work any effective value upon the issue of priority. Robinson on Patents, Sec. 79, p. 121. In November Langmuir made other experiments but these he concedes were for the purpose of ascertaining the accuracy and existence of certain laws of physics. I find no evidence that he then thought of applying the scientific principles in which he was interested to any practical result in the useful arts. Consequently, there is no satisfactory evidence that Langmuir had a conception of the device of the patent before the end of November. "It is not while the creative energies are at work shaping and sharpening the idea of means that the conception of the invention becomes perfect. It is when these energies have ceased to act, when the idea stands before the mental vision of the inventor as clearly as a concrete invention before the eyes of an observer, that the conception is complete and the work of reduction is ready to begin." Robinson on Patents, Sec. 379. Tested by this rule even the statements of Langmuir to Coolidge in December, 1912, did not reveal a complete idea of means and, consequently, did not disclose a complete conception within the meaning of the patent law. It was not until March 21, 1913, as I read the record, that Langmuir's conception or idea of means to a useful end began to take shape. He then made a record of it in these words: "Now what I intend to do is to construct an audion which will oper-

ate entirely and exclusively on the electron discharge. I shall attempt to get the vacuum so good that positive ions are present in negligible amounts." It is not necessary to inquire when the conception became complete and his idea reduced to practice for Arnold had had the conception long before and had proceeded diligently to reduce it to practice.

The bill of complaint in this case must be dismissed.

(sgd) HUGH M. MORRIS, J.

January 3, 1928.

The Opinion of Judge Woolley.

IN THE
UNITED STATES CIRCUIT COURT OF APPEALS
FOR THE THIRD CIRCUIT.

GENERAL ELECTRIC COMPANY, *Appellant,* v. DEFOREST RADIO COMPANY, *Appellee.*	March Term, 1928. No. 3799.

WOOLLEY, *Circuit Judge*, dissenting:

I am constrained to dissent from the judgment of the court holding the Langmuir patent No. 1,558,436 valid. I have the same trouble that other tribunals have had throughout the twelve years of the patent prosecution and five years of the patent's life in finding precisely what Langmuir invented. My trouble, like that of others, has been increased by the difficulty which attorneys for the patent have had in defining the invention and by the difference between their definitions and the claims of the patent.

This is more than a mental disturbance, for manifestly a patent to be valid must relate to some invention, something patentably new and useful, and must disclose the invention so that a court, looking through the eyes of those skilled in the art, can see what it is.

The art—really two related arts—is that of wire and wireless telephony, the latter commonly called radio. The invention relates generally to an electron discharge device comprising the familiar vacuum tube in which the customary electric current is carried by negative charges called electrons from the cathode to the anode, sometimes associated with a grid, and relates particularly to a vacuum space so free from gases as to avoid ionization. If the parts and principles of the mechanical construction were new and the gas evacuation old, there might be invention; and also if the structure and its principles were old and the gas evacuation—high vacuum—were new, still there might be invention. But the essential parts and principles of the mechanism, comprising a tube, cathode, anode and grid, were old, and high vacuum in the tube also was old. So the inventor was forced to admit the presence of these old elements, yet, still insisting he had created something new, he was compelled to avoid the common art terms applicable to these elements and particularly that of "high vacuum" in disclosing his invention and use technical terms which, as I understand them, mean the same old things. With this necessarily general preface to a highly complicated situation arising out of a difficult art, I come to the matters in hand.

In an effort to find what Langmuir invented, it is well to begin at the beginning. I shall therefore turn to his application for a patent, for in that instrument must appear the substance of the invention as the basis for subsequent amendments and for the patent as it eventually matured.

A recital of the prosecution of a patent application through the Patent Office is dreary reading yet, in this instance, it shows quite clearly that even the applicant

was far from certain what he had invented. Naturally I hesitate to say this about Irving Langmuir, a great physicist, yet, saying it with entire respect, I am convinced that the history of the application establishes that fact and therefore is pertinent to the ever present inquiry: What did Langmuir invent?

The patent issued on October 20, 1925. The application was filed on October 16, 1913; renewed March 14, 1916. These are critical dates. The original application contained five claims; two for process of removing ionizable gas from vacuum electron discharge devices, that is, in plain words, for obtaining a high vacuum, and three for methods of preparing such devices, and no claims for discharge devices themselves. The specification conformed to these claims, referred to the art, stated the problem, disclosed construction adapted to the operative principle of such tubes and showed how they can be "evacuated" of gases by heating the glass walls, heating and bombarding the metal parts thereby expelling occluded gases, and drawing off both free gases and expelled gases "by a suitable evacuating means, for example, a Gaede molecular pump."

It should be noted that when the application was filed in 1913 the radio art was in its infancy but that, in 1925, when the patent issued, the art had attained an amazing growth. It is pertinent to inquire what happened to the application during this span of twelve years during which the mysteries that had enveloped the early art were largely dispelled and replaced by a broad knowledge of its principles.

After the application was filed in 1913 it lay practically dormant for several years, the applicant filing enough amendments by additions and cancellations to keep it alive. Amendments to the specification occurred as fol-

lows: two in 1913; eight in 1914; one in 1915; five in 1916; three in 1917; three in 1919 and forty-five in 1925, the year the patent issued.

Amended claims were filed and additions thereto and cancellations thereof made as follows: four in 1913; fifteen in 1914; twenty in 1916; five in 1917; nine in 1919; five in 1921 and forty-two in 1925, the year of the patent.

Analyzing these amendments, it appears that the five original claims (which were for process and method) were at different times wholly cancelled. Late in the year 1913 Langmuir first made claim to invention of a structure or device, that is, to invention of a tube. This he did by four claims. The first was amended four times and cancelled in 1925. The second also was amended four times and cancelled in 1925. The third was amended four times and was not cancelled. The fourth was amended once and cancelled in 1925. Of the thirty-two claims allowed in the issued patent, four are for method and process, being amplifications of the original method and process claims cancelled; twenty-eight are for a device. Of these device claims one was filed by amendment in 1913; one in 1917; nine in 1919; three in 1921 and fourteen in 1925, the year the patent issued. Bearing on the question whether Langmuir knew and disclosed in 1913, or indeed in succeeding years, what he had invented, it is significant to note that during twelve years, and mainly in the latter part of that period when the art had grown and reached a high stature, he rewrote, by sixty-seven amendments, the major part of his specification and cancelled all the original method and process claims and by one hundred amendments added, changed and cancelled claims until finally he was allowed the thirty-two claims of which twenty-eight, the claims for a device, are entirely new. It would be in-

structive, yet impossible within the permissible bounds of an opinion, to trace the progressive changes from the method and process claims of the original application to the device claims of the matured patent. But device claims having been allowed, they inevitably bring into the case certain devices of the prior art of which two are presently pertinent.

Long before Langmuir applied for a patent, Fleming, an English inventor, brought into a very feeble art a practical electron discharge device, comprising a cathode and anode in a vacuum tube. Also long before Langmuir's application, DeForest improved on Fleming by producing an electron discharge tube which he described as an oscillation detector and called an "audion." The improvement consisted in adding a grid to Fleming's elements. The construction and functions of both devices are given in an elementary way in the opinion in Westinghouse Electric & Mfg. Co. *v.* DeForest Radio T. & T. Co., 21 Fed. (2d) 918, 919. The audion as conceived by Fleming and improved by DeForest at once became and has ever since continued to be the basis of the modern art of transmitting sounds great distances both by wire and through the air. Just here dates are important. A patent for the audion (No. 879,932) issued to DeForest in 1908. The audion vacuum tube was therefore in existence and its principles of operation presumably known by Langmuir when in 1913 he filed his application for a method of evacuating such a tube, although he had not seen one until that year. In 1912 or 1913, the American Telephone & Telegraph Company, committed to the operation of transcontinental telephony by the opening of the San Francisco Fair, acquired rights under the DeForest patent and, first exhausting the gas and heightening its vacuum, used the DeForest audion

as an amplifying telephone relay, thus making possible the first transmission of vocal words from coast to coast by wire. In 1917 the DeForest Radio Telephone Company, assignee of the DeForest patent, granted (with certain rights reserved) a license to the Western Electric Company to make, use and sell the invention for certain purposes with the right to grant sub-licenses. In 1920 the General Electric Company, the plaintiff in this suit and the assignee of the Langmuir patent in suit, acquired through mesne conveyances a sub-license to make, use and sell the DeForest audion, DeForest Radio T. & T. Co. *v.* Radio Corporation of America, 20 Fed. (2d) 598, 599, 600, which (probably with a heightened vacuum) it did on a vast scale until the DeForest patent expired in 1925, the year in which the patent in suit, after twelve years of travail in the Patent Office, issued to Langmuir, assignor to the General Electric Company, for an electron discharge tube including the essential parts and now universally accepted principles of the Fleming-DeForest tube. The Langmuir patent now completely covers the field previously occupied by the audion of the expired DeForest patent, and will, on the decree of this court, continue to cover it for twelve years more; hence the importance of this litigation.

Turning to the patent as it issued, the specification must first be looked at, for it contains some references to the behavior of electricity in a vacuum tube, old and well known, which are necessary to an understanding of the case. First there is a description by words and diagrams of mechanism for a vacuum tube. If new, this, it would seem, is unimportant as the specific mechanism is not claimed. Its importance resides in the fact that the patented device comprises the three elements of the general mechanism found in the art—the cathode, anode

and grid, variously positioned in a vacuum tube to get the best electrical result—and in the fact that, as I read the record, these three elements, separately and in combination, operate on the same principle in which they operated in the art. Describing their operation, as the art then knew it, Langmuir said:

> "The passage of an electric current across a tube ordinarily involves the movement of negative charges called electrons which, under the influence of the impressed voltage, pass from the cathode to the anode through the vacuous space. If these electrons when moving above a certain velocity collide with gas molecules they tend to ionize the molecules, splitting them up into electrons and larger and more slowly moving ions. Under these circumstances the phenomena of conduction across the tubes are the result of the action and interaction of electrons and the ions; * * * The cathode under these conditions is disintegrated, * * *, which causes its rapid destruction * * * The bombardment of the cathode by positive ions also causes heating of the cathode. The ionization of gases at low pressures by collision with electrons occurs at definitely determinable voltages, these voltages being known as the ionization voltages * * * (It should, for later use, be noted here that Langmuir said nothing about gas being a supposed medium for conducting electrons from one electrode to the other.)
>
> "If for a given cathode temperature the voltage is sufficiently high to cause all the electrons emitted or liberated at the cathode to be drawn away, then a further increase in voltage produces substantially no change in the current. The current thus determined is called the saturation current, and the range of operation in which the current is substantially independent of the voltage or approaches this condition may be called the saturation range

or more briefly designated merely as saturation. If for a given cathode temperature the voltage is not high enough to cause all of the electrons which are emitted or liberated at the cathode to be drawn away, the operation occurs in a range below the saturation range. Operation in this range may be spoken of as operation below saturation."

Predicated on these two definitions of ionization and saturation Langmuir by claim 2, which has been treated in this litigation as a typical claim, said that his invention is:

> "A discharge tube having a cathode adapted to emit electrons and an anode adapted to receive said emitted electrons, the tube walls being fashioned or shaped to permit the direct passage of a useful proportion of said electrons from cathode to anode, the gas content or residue of said tube and the relation of the parts of the tube being such that the tube is capable of being so operated in a range, below saturation and materially above ionization voltages that the space current is governed or limited by the electric field of said electrons substantially unaffected by positive ionization."

That, as I read it, simply means "high vacuum," for a tube properly fashioned and shaped by skilled workers and highly (thoroughly) evacuated of gases—free and occluded—will in conjunction with a two electron group or with a group of two electrons and a grid produce these results; both groups, then and now, being in common use for different purposes by the art and by the plaintiff itself.

For the purposes of this case, vacuum means gas evacuation, high vacuum means vacuum above the ionization point, and, by the same token, a high vacuum

tube means a non-gaseous tube. If the language of the claims means high vacuum, it is prior art, for the art was entirely familiar with the fact and effect of such a vacuum; and if prior art, Langmuir invented nothing.

When the patent came into litigation in this case in the District Court of the United States for the District of Delaware the learned trial judge, having trouble with the claims, endeavored to get from the plaintiff a definition of the invention, asking time and again, as did this court on appeal: If not high vacuum, what is the invention? An answer to this question seemingly had its difficulties. The plaintiff, of course, could not say that the invention was high vacuum alone, or high vacuum in combination with Fleming and DeForest parts alone, for that would be an admission of old art and would instantly avoid the patent. It was forced to admit that the Langmuir device included all these old elements but claimed it included "something else." So, eventually, in order to show this something else—something new—it produced, under the insistence of the trial court, this carefully constructed definition of Langmuir's invention, on which the case was tried below and on which it was first argued and decided in this court on appeal:

> "The Langmuir invention is a coordination of elements having a new functional relation between various factors, producing a new result. It is not a matter merely of maintaining a certain vacuum, far less of *producing* a certain vacuum which will be destroyed the moment the tube begins to operate. It involves primarily a relation between the shape, size and space relation or "geometry" of the parts of the tube and the nature and pressure of the gas therein contained, coordinated and adjusted with respect to the conditions of the electric circuit."

That, I surmise, would be a bad patent claim. However, as it was intended to describe the invention more clearly and more definitely than Langmuir had disclosed it in the patent claims I shall take it as it is written and try to find what it means. I discern in its generalization three factors: (1) gas pressure in the tube; (2) "shape, size and space relation or geometry of the parts of the tube"; and (3) the relation of one to the other.

The first factor of gas pressure, or, more properly, the lack of it, if it means anything, must mean a minimum of gas. This in turn means high vacuum. If it does not mean high vacuum there is no new vacuum factor of invention in the device, for low vacuum was old and that is an end to the case. If it does mean high vacuum then again it is not new, for high vacua, their uses and effect and how to produce them, were long known and practiced in the art.

The second factor, or "geometry," of the physical tube elements is not, so far as the claims reveal, involved in the invention. The physical elements themselves were old. This the plaintiff admits. Though differing in shape from some others, they are not claimed to be inventively novel in themselves. Indeed, each claim describes the invention not so much by its parts as by its characteristics of operation and results—characteristics inherent in any electron discharge tube possessing a high vacuum. Nor was this an inadvertence for when the Examiner, on rejecting certain device claims on prior art references, said:

> "If applicant's device is an improvement over the reference he should define the difference by structural limitations," the applicant (Langmuir) replied by saying:
>
> "The 'structural limitations' in this case are to be found in the *difference of vacuum*."

So, thus far, the invention, with old parts and a high vacuum, gets back to the question whether there was invention in the "difference" between low vacuum and high vacuum, a difference existing in and known to the art.

The third factor, the relation of the two factors of gas pressure and physical parts, appears nowhere in the claim unless it be implicit in the words "the gas content or residue of said tube and the relation of the *parts* of the tube being such" as to produce a certain result. (Gas pressure is scarcely a *part* of a tube.) If it is so implied, Langmuir cannot claim invention by implication. The claim therefore is void for inadequate disclosure. If it is not so implied, there is no claim for the third factor.

Whether I am right or wrong in this analysis of the plaintiff's statement of Langmuir's invention or in my disposition of its elements is not important for the validity of the patent depends not on the plaintiff's conception and definition of the invention but on the claims of the patent.

So I come back to the claims of the Langmuir patent to find Langmuir's invention. But before doing that I am arrested by still another entirely new definition of Langmuir's invention, this time made by the court in its opinion. The court did not adopt the plaintiff's definition of coordinating elements with functional relations but, stating that a non-gaseous electron discharge device did not exist before Langmuir, found the invention to reside in his producing a non-gaseous tube in place of a gaseous tube of the prior art or, in other words, in substituting a high vacuum for a low vacuum, the very thing which all along the plaintiff was forced to avoid in its definition because it was old. Without conceding its predicate, I agree with the court's succinct definition of

the invention; but as the invention so defined was old I cannot agree to hold a patent for it valid.

It now appears, and I say this with entire respect, that in interpreting and sustaining the patent broadly for a non-gaseous tube the court has given the plaintiff more than it ever dared to claim. A high vacuum or non-gaseous tube being old, the plaintiff knew that an admission that the invention was a non-gaseous tube and nothing else would defeat the patent. Langmuir also must have known that a non-gaseous tube was old for otherwise, if he had believed he was the first to conceive and make one, he could, and doubtless would, have claimed it in a half dozen words: "A non-gaseous discharge tube," or "an electrical discharge device with a high vacuum tube," whereas in his original application for a patent he made no claim for a tube of that kind or, indeed, for a tube of any kind, the inevitable inference being that at that time he thought all he had invented was a new method or process of gas evacuation, that is, a new way to produce an old thing. But that the plaintiff realized the necessity of claiming for the invention something more than a high vacuum tube or non-gaseous tube is evidenced by its earnest and repeated contentions that Langmuir's invention, while including a non-gaseous tube—high vacuum—admittedly old, included "something else," that something else being disclosed by the remainder of the long claims and interpreted in its quoted definition. The plaintiff nowhere and at no time has claimed that Langmuir invented a non-gaseous tube *per se*. And wisely so, for it well knew that, while not in universal use, non-gaseous tubes were in commercial use before Langmuir for some purposes and that gas evacuations were as thorough as the instrumentalities of

the art in 1913 would effect, and that was substantially above the ionization point, which is the crux of this case.

Returning to the patent claims and using claim 2 for convenience, it appears that the invention is an electron discharge tube which is capable of being operated below saturation and above ionization voltages. Langmuir called this a "pure electron discharge device"—"pure" because unaffected by gas ionization which is either entirely absent or negligible.

Electricity is an elusive subject. Therefore I shall, for the immediate purpose, restate in plain words, if I can, the theory of ionization.

Ionization is an effect produced by passing an electric current through gas which remains in a vacuum tube when it has not been thoroughly evacuated. The myriads of electrons, when passing from cathode to anode above a certain velocity, collide with and break up the molecules of gas present and charge the resultant broken parts or ions with positive charges of electricity. Thus electric reaction is inevitable. The ions (with their positive charges of electricity) fight against the electrons (with their negative charges) in the normal flow of the latter from cathode to anode resulting, at high voltages, in a blue glow which is the indication of bad action, a thing to be avoided. The central point of this statement is that ionization occurs at certain voltages in an electron discharge tube when, not being thoroughly evacuated, it contains air or gas, whether gas free in the tube or gas occluded in its parts and liberated by heat during operation. The amount of ionization depends upon the amount of gas present. Langmuir prescribed in his specification that occluded gas should be expelled from the tube parts; from the tube by heating its glass walls; from the cold electrodes by electron bombardment—the liberation of

gas by the electric discharge itself; and from the incandescent cathode by the heat of an electric current; all old; and after this, that both the expelled gas and free gas should be pumped out of the tube during the heating process (old) by "a suitable evacuating means (old) for example, a Gaede molecular pump," then a new German invention.

Thus the capital requirement, if not the sole requirement, of Langmuir's claimed invention, is as nearly as possible to withdraw from the tube all gas, free and occluded; in other words, to obtain as high a vacuum as possible. When that is done ionization is avoided and a pure electron discharge follows. Was this new with Langmuir?

Langmuir was met in the Patent Office with the Law Examiner's statement that:

> "It is apparent after a review of the record that there is no single element which is broadly novel in the assemblage of elements making up an electron discharge device of the character defined in the issue. *An evacuated tube having therein an incandescent electron emitting cathode and an anode was old prior to the filing of Langmuir's application, and methods of attaining high vacua, sufficient to give a relatively pure electron discharge in a properly designed tube were also well known and available to persons skilled in the art.*"

Was that statement of the Law Examiner correct? I think it was. Just here occurs my sharpest departure from the opinion of the court which is based, as I have before stated, on what I am constrained to believe is an erroneous theory or finding that all discharge tubes before Langmuir were gaseous and that Langmuir's invention is a non-gaseous tube.

If that was his invention, clearly he must have been the first to conceive it and reduce it to practice. That the Examiner was right in saying that high vacua in electron discharge tubes were old before Langmuir and that a pure electron discharge—the inevitable result in a high vacuum non-gaseous tube and an impossible result in a gaseous low vacuum tube—also was old is sustained by many prior publications and patents. The same prior publications and patents contradict, I think, the court's holding that Langmuir was first to make and invent a non-gaseous tube. They are so numerous that it would not be permissible to quote them in an opinion. I shall therefore do nothing more than cite a few of them, ranging from 1881 to 1912, found in the record and to be used by anyone who should desire to check up this statement or who may be charged with the duty of retrying the issue. They are: Lilienfeld, Fleming, Doane, VonBaeyer, Bissel & Hagen, Malignani, Edison, Dwyer, Duncan, Leonard, Soddy, Thatcher, Ghild; illumined by the testimony of Waterman and Chaffee.

On these references I stand; and on them I would hold the patent invalid for want of invention.

Passing from the literature and patents of the prior art as affecting the validity of the patent for want of invention, I come to the question of prior use. The trial court found the patent also invalid because of prior use by DeForest on evidence as to which there is little dispute on the facts as distinguished from inferences. The test is the voltage at which ionization ordinarily occurs in a "gassy" tube. It is given at from 20 to 30 volts. That is not disputed; they are Langmuir's figures.

Prior to August, 1912, DeForest was the electrical engineer of the Federal Telegraph Company of California and was engaged in developing the transmission and re-

ception of messages by radio. In this work he used his oscillation detector or audion then normally having a gas content. It was a "gassy" tube. But desiring to use it not as a detector but as an amplifier, as later it was almost universally used and indeed as made for that use by the plaintiff itself under license and by the Westinghouse Electric & Manufacturing Company, its sublicensee, he had the audion exhausted of gas as far as it was possible in that day. That is, he sought and obtained as high a vacuum in the tube as existing means would produce. When the vacua were too low and the amplications poor he complained to the manufacturer and had the tubes re-exhausted. During that period (1910, 1911 and 1912) the Federal Telegraph Company used DeForest's amplifying audion at 54 and 67½ volts. This was possible only because he had exhausted the tubes of gas, which otherwise would produce ionization at 20 to 30 volts, and thereby heightened the vacuum above that danger line. This was "high vacuum" within the definition of vacuum above the point of ionization and was therefore high vacuum within the sense of those words as used in this case. It was not so high as that later attained by more modern means, for instance the Gaede molecular pump, which had just come into the art at the time of the patent application, referred to by Langmuir in his application and invented not by him but by Gaede. I agree with the court that DeForest did not then understand the change in operative principle for in later years he expressed views contrary to those advanced both before and after that time. But DeForest did change the vacua of his tubes in changing their function from detectors to amplifiers. Whether he knew the principle of the change is of no consequence. The fact is he did it. And he did it before Langmuir. And by

doing it he got rid of the ionization of low vacuum and obtained, and put into commercial practice for nearly three years before Langmuir, the very electron discharge of Langmuir's claimed invention.

What I have said about the device claims applies equally to the method and process claims.

On the subject of validity as involving invention I shall conclude this phase of the discussion by referring very briefly to the claimed advance made in the art by Langmuir's invention, matter with which the plaintiff very earnestly began and ended discussion in its brief and at the argument and matter by which the court was impressed. Admittedly, when invention is in doubt—yet *only* when it is in doubt—favorable reception by the art may be placed in the scale. As the four judges who heard this case have divided evenly on the question of invention, I shall, for that reason only, assume there is doubt as to invention. The plaintiff says that today everybody uses "the Langmuir tube," a name given it not by the art (as the plaintiff frankly admitted at the argument) but by the plaintiff itself; that Langmuir, seeing through the mysteries of the art, made an invention that revolutionized the industry and made possible the transmission of sounds through the air for great distances which without his invention would be impossible.

Much litigation in respect to the radio art has drifted to this circuit. Oddly enough, in every case the plaintiff has claimed for his invention the whole credit for its growth. I am satisfied from the number of cases we have heard that the whole credit for the amazing advance of the radio art cannot be given to any one invention or even to a few of them. In truth, the art is the product of innumerable impulses. The original impulse was, of course, the vacuum tube appearing years

ago in the incandescent lamp art. Another impulse given in the incandescent lamp art and transferred to the radio art was that of the Just and Hanaman unstable squirted tungsten filament displacing Edison's bamboo filament; still another was Coolidge's method for obtaining a filament of pure tungsten, strong and stable. Impulses in the radio art itself came from many inventors. At one time there were seven thousand applications for patents pending in the radio section of the Patent Office. To mention only one or two inventions, they include discharge devices of the Fleming two electrode type and the DeForest type with a grid added to Fleming, the feedback circuit invented at different times by DeForest, Armstrong, Langmuir and Meissner. There are many more, without any one of which it has always been said by the particular inventor that the art would have gotten nowhere. And now the plaintiff here says the same of Langmuir. Important and indeed great as some of these inventions were, no one of them is entitled to all credit for what has been accomplished in this great art, for the art has been impelled forward by hundreds of inventors and thousands of skilled workers. What Langmuir claims to have done—procured pure electron discharge above ionization voltages in tubes of the DeForest type—appears to me to be the natural growth of the art, begun by others before Langmuir and by them reduced to practice with means then available, and developed to their later perfection during the twelve years of his patent prosecution through the Patent Office.

I thought after the argument, and still think, the Langmuir patent invalid because of lack of invention and prior use. If I am wrong and the patent really involves invention, then, again, I think it invalid for, as I read the evidence, Langmuir was not the first and original

inventor. On this point, to avoid repetition, I refer and subscribe to the opinion of Judge Morris holding on evidence substantially greater than the evidence in the interference proceeding that, if invention, Arnold was the first and original inventor.

And so this court, one judge dissenting, affirmed the decree of the District Court, on its opinion, holding the Langmuir patent invalid.

In due course the plaintiff filed a petition for rehearing based on this proposition:

> "In simple language, Langmuir's invention consisted in taking out the conductor (gas) which was in the Fleming valve and the DeForest audion and putting nothing in its place; he dispensed with what was regarded as an essential element in the operation of the tube (gas) and by doing so made a tube which worked infinitely better."

The petition was allowed and the reargument was based on this entirely new statement of Langmuir's invention made for the first time four years after suit was brought, five years after the patent was issued and seventeen years after the application was filed. Of course if the facts asserted were facts established by the evidence there would be no doubt about what Langmuir did and no doubt that it was invention and, if claimed, no doubt he was entitled to a patent.

The plaintiff rests its proposition upon its own statement that "Both Fleming and DeForest depended upon the conductivity of gas as the fundamental basis of the operation of their tubes." It makes this statement without distinguishing between detectors and amplifiers and supports it by carefully selected quotations from scientific publications in the early days of the art ranging from 1905 to 1912 (one in 1915) when scientists were feeling

for the theory of electron movement in electron discharge tubes, some of whom based it on conduction by rarified gases or air, some on conduction by ionized gases, and some not on conduction at all but on free passage of electrons through space in a high vacuum, that is, in the absence of gas or air. And in addition the plaintiff to support its statement points to an adverse criticism by DeForest in 1915 of Langmuir's "extremely high vacuum" quoted in the court's opinion. The plaintiff ignored all the testimony on the subjects of prior art high vacua and pure electron discharge, which means absence of gas as a conductor, their advantages and uses, to which I have previously alluded with citations.

Of course, if the belief and practice of the art were that gas conducts the electrons, that gas therefore is necessary to conduction and Langmuir discovered it to be wrong, that in fact gas is an enemy to conduction, and omitted gas as an element in his tube yet obtained the same or a better result, clearly he made an invention. These are the things which now the plaintiff and also the court say he did. But Langmuir did not say so. If that was his invention he should have disclosed it in his claims for we are called upon to judge the patent on Langmuir's disclosures, not on the plaintiff's definitions of his invention. To be sure, he did refer in his specification to several tubes—the Geisler tube and the Roentgen X-ray tube—"whose operation depends upon gas ionization." He might, more or less correctly, have added to the list detectors with gas content, then and now in common use for certain purposes, whose usefulness depends on their sensitiveness and their sensitiveness on gas content. But he nowhere said in his patent that before his invention electron discharge tubes used for amplifying purposes in order more faithfully

to reproduce sounds (one of the purposes of the DeForest audion and the thing we are dealing with in this case) depended on low vacuum or that the art regarded, as an essential element of such a device, gas as a conductor, for he probably knew the contrary was true. To show that the plaintiff's last definition of Langmuir's invention is without foundation in the evidence I refer to, but shall not repeat, what I have said about prior knowledge and prior use of high vacuum tubes. I shall endeavor, very briefly, to show that Langmuir by his own words contradicts the plaintiff's last definition of his invention and refutes the theory on which the court has in part based its judgment.

In Langmuir's original specification he stated that when there was enough gas in the tube to become ionized by the discharge of electrons "The positive ions (gas molecules) *take part* in the *conduction* of current, giving at first erratic readings on measuring instruments connected in circuit," which is what the plaintiff now says. Continuing, he said, that the audion, the DeForest tube, was a device that took advantage of that phenomenon. *But he cancelled the quoted statement before the patent issued.* At the trial he was examined with respect to that statement in his patent application and was asked whether the sentence would be true if it read; "The positive ions take part in the conduction of current by acting as *conductors* or carriers of current." He answered: "In my opinion the sentence would have *no sensible meaning* if the word 'conductor' was left in for *it is inconceivable that ions could be conductors of current.* I will, therefore, confine myself to the case where the positive ions act as 'carriers.' With this correction I can say that the statement would not have been true."

With this cancellation and explanation Langmuir rested. Neither by amendment nor in his testimony did he again advert to a prior art theory of gas conduction which the plaintiff now says "was regarded (by the art) as an essential element of the operation."

In the interference proceeding Langmuir testified with respect to the early work of Lilienfeld, as follows:

> "Lilienfeld proved beyond question, I think, that he obtained discharges in some cases at least, in which the effects that he measured *were not dependent upon gas ionization* * * *
>
> "Lilienfeld probably succeeded in obtaining a discharge *high vacuum substantially free from effects of positive ionization* in the device he described in his 1910 paper * * *
>
> "Lilienfeld in his experiments of 1910 heated the walls of the vessel, *he reduces the gas pressure to a low value*, and in some of his experiments *he heated his electrodes* by *electronic bombardment* * * *
>
> "*Heating of glass and electrodes, and exhaustion to low pressure*, are elements which were used by Lilienfeld and were known *prior* to Lilienfeld's article * * *
>
> "Factor No. 1 which I gave in answer to XQ84, viz., that the bulb should be heated *during* exhaust to a temperature materially higher than the operating temperature, was used by Lilienfeld in much of his work * * *
>
> "Factor No. 4, which is that which I gave in the first part of my answer to XQ87, refers to the lowering of the pressure to such a point *that a further lowering brings about no further change*. In many of Lilienfeld's experiments, this condition *was realized*."

VonBaeyer stated as early as 1909 that his "experiments were of course carried out in the highest possible

vacuum to avoid the influence of ionization." Langmuir admitted that "Wehnelt claimed that * * * currents of the order of 10 milliamperes could be obtained even in the highest vacuum."

Referring to an interview with Richardson in 1912 Langmuir said:

> "Richardson * * * expressed himself as confident that even in the highest vacuum thermionic currents could still be obtained."

Langmuir admitted in the interference proceeding that "prior to 1912 (the year before his application) there were some experimenters who took precautions to remove gases from the walls, from vessels and from electrodes."

This, I think, shows that the reargument, based on an incorrect premise, should leave undisturbed the court's first finding that the patent is invalid.

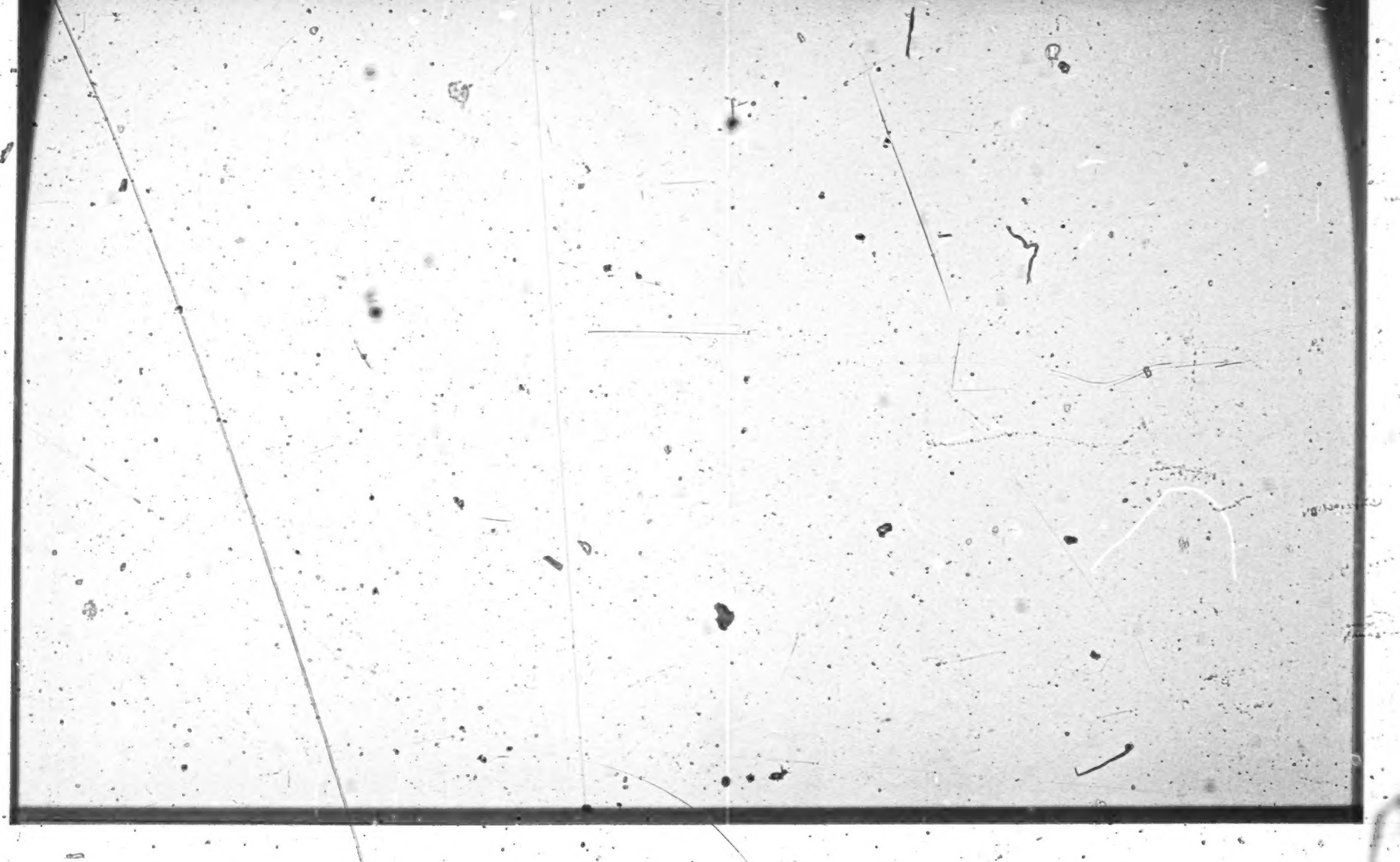
The plaintiff, however, prevailed. The court reversed its previous decision and will now enter a decree holding the patent valid. From the opinion announcing its judgment, in so far as it will reverse the decree of the District Court on the first (Langmuir) patent in suit, I dissent.

This is a long dissenting opinion. In view of the gravity of the Court's decision and its effect upon the art I make no apology for its length. I frankly admit that it is written with the hope that it will arrest the attention of the reviewing court.

A true Copy:

Teste:

Clerk of the United States Circuit Court
of Appeals for the Third Circuit.



FILE COPY

FEB 2 193

Supreme Court of the United States

October Term, 1930.

No. 630.

DEFOREST RADIO COMPANY,

Petitioner,

v.

GENERAL ELECTRIC COMPANY,

Respondent.

OPINION OF COMMISSIONER OF PATENTS IN ARNOLD *v.* LANGMUIR INTERFERENCE NO. 40,380

THOMAS G. HAIGHT,
SAMUEL E. DARBY, JR.,
Counsel for Petitioner.

Hearing:
Aug. 17, 1923.

IN THE

United States Patent Office

ARNOLD *v.* LANGMUIR.

PATENT INTERFERENCE No. 40,380.

APPEAL FROM EXAMINERS-IN-CHIEF.

ELECTRIC DISCHARGE APPARATUS AND THE PROCESS OF PREPARING THE SAME.

Application of Harold De Forest Arnold filed November 2, 1915, No. 59,210.

Application of Irving Langmuir filed March 14, 1916, No. 84,242, for renewal of application filed October 16, 1913, No. 795,610.

MESSRS. DE WITT C. TANNER and JOHN G. ROBERTS and MR. GEO. E. FOLK for Arnold. MR. CARL A. RICHMOND of counsel.

MR. ALBERT G. DAVIS and MR. ALEXANDER D. LUNT for Langmuir.

This is an appeal by Arnold from a decision of the examiners-in-chief affirming the examiner of interferences awarding priority on all counts to Langmuir.

The issue is a thermionic tube in which there may be a pure electron discharge, as distinguished from a discharge through gas which is ionized, so as to be useful for such purposes as a telephone relay, a wireless detector or amplifier, a rectifier of alternating current and possibly a generator of X-rays. It is the device of defendant in Hewitt *v.* American T. and T. Co., 272 Fed. Rep., 194, and 272 Fed. Rep., 392. The invention is exemplified by a structure such as the well known De Forest audion or Fleming Valve (see Marconi Co. *v.* De Forest Co., 236 Fed. Rep., 942), modified so that there is present during operation too little gas to modify or affect the pure electron discharge from the cathode.

The applications were filed in 1913 (renewed in 1916) and 1915. After the interference was declared, Arnold moved to dissolve on the ground that the issue was unpatentable. In February, 1917, the Commissioner ordered testimony to be taken on the question of patentability and between July, 1917, and January, 1920, over 1650 printed pages of testimony accompanied by a great mass of exhibits were introduced. Much of this testimony should not have been taken since it related to priority alone. Motions were made to amend the issue and some counts were withdrawn. The law examiner rendered a seventeen page opinion settling the counts and finding patentability. Subsequently, by stipulation, other counts were added and the issue fixed into thirteen counts, of which the following are sufficiently illustrative:

> 1. A high vacuum electron discharge device comprising an envelope, an incandescent cathode, and an anode, the space in said envelope being evacuated to such degree that the passage of current produces no appreciable positive ionization when the impressed voltage is as high as 200 volts.

5. A discharge tube having electrodes at least one of which is adapted to emit electrons, the gas content or residue of said tube and the relation of the parts of the tube being such that the tube is capable of being so operated in a range below saturation and materially above ionization voltages that in that range the space current is governed by the combined effect of the electric field of said electrons and the potentials applied to said electrodes, the governing or limiting of the current being substantially unaffected by positive ionization and by secondary electron emission from the walls of the tube.

7. A discharge device comprising a tube and electrodes therein one of which is adapted to emit electrons, the degree of evacuation and the relation of the parts of the device being such that the device is capable of being so operated, when voltages materially higher than ionization voltages are impressed on electrodes of the device and when the electron emission has any value such that the space current is below the saturation region at such voltages, that the line obtained by plotting the logarithms of any values of said current below the saturation region as ordinates against the logarithms of the corresponding values of said impressed voltages as abscissas is straight and continuous.

9. A discharge device comprising a tube and electrodes therein one of which is an electron emitting cathode, the degree of evacuation of said device and the relation of the parts of the device being such that the device is capable of being so operated, when voltages materially higher than ionization voltages are impressed on electrodes of the device and when the electron emission is such that the space current is below the saturation region at such voltages, that said current is substantially independent of the cathode temperature and unaffected by secondary electron emission from the walls of the tube.

11. A discharge tube having a cathode adapted to emit electrons, an anode adapted to receive electrons and tube walls fashioned or shaped so as to permit the free passage of a useful proportion of said electrons from cathode to anode, the gas content or residue of said tube and the relation of the parts of the tube being such that the tube is capable of operation with stable and reproducible results substantially unaffected by positive ionization, with currents of at least 5 milliamperes and with voltages of at least 200 volts.

13. The method of controlling an electric current in one circuit by an electromotive force in another circuit which consists in causing said current at voltages materially above ionization voltages to pass as a discharge across a vacuous space between an electron emitting cathode and an anode, maintaining a high vacuum in said space, governing or limiting the current by a space charge effect in said space substantially unaffected by positive ionization, and superimposing the effect of said electromotive force on said space charge effect to control said current in a stable and reproducible manner.

The counts are ably and clearly analyzed by the examiners-in-chief thus:

A thermionic tube which operates solely by electron discharges or currents has certain distinctive characteristics by means of which the presence of the invention may be recognized, and the counts have been so worded that each brings out one or more of these characteristics. For example, count 1 specifies that the envelope of the tube is evacuated to such a degree that the passage of current produces no appreciable positive ionization when the impressed voltage is as high as 200 volts. Thus the count distinguishes from the prior art, not by features of structure, but by a characteristic which is manifest while the device is operating at or above a certain

voltage. The audion is not evacuated to the high degree that count 1 calls for and, at an impressed voltage of about 30, ionization occurs. Count 5 specifies that the relation of the parts of the tube and the degree of evacuation are such that, when operated in a range below saturation and materially above ionization voltages, the space current is governed by the combined effect of the electric field of the electrons and the potentials applied to the electrodes, the governing or limiting of the current being substantially unaffected by secondary electron emission from the walls of the tube.

When a thermionic tube is operating by a pure electronic discharge at a voltage substantially below saturation, the current varies in substantial accordance with the 3/2 power of the impressed voltage. If the voltages be plotted as abscissas and the currents as ordinates, the result is a curve that gradually rises and turns toward the left—the curve of the 3/2 power. This obtains while there are plenty of electrons emitted from the cathode, at the temperature at which it is heated, to make up the increasing current. But the number of electrons emitted varies with the temperature of the cathode and that temperature is generally maintained constant. Consequently, a voltage will be reached which is capable of forcing the electrons across the space more rapidly than they can be emitted. The result is the flat-topped curve showing saturation. The tubes of the issue are operated at voltages above that of ionization and below that of saturation, and the voltage current curve follows the 3/2 power law. This is one of the characteristics of the tubes; and a tube that has such a characteristic operates by a pure electronic discharge and is a tube of the issue.

Ionization occurs when there is gas within the tube during operation. This gas may be normally free, as when mercury vapors are present, or it may be absorbed or occluded in the electrodes, particularly the anode, and in the glass walls of the tube.

The electrodes and walls act like sponges, taking up the gas when cold and again giving it off when heated during operation. A tube which has gas either in a normal free state or occluded in the electrodes or walls is subject to ionization; and ionization takes place when the voltage rises sufficiently to produce it. About 15 volts is sufficient to give this result. But a tube which operates by ionizing a gas does not respond to the 3/2 power law and is not a tube of the issue. Excessive ionization is usually accompanied by a blue glow or haze; but such a glow is not a reliable test, as both parties admit, since a tube that does not show blue glow may produce ionization to such a degree as to cause it to depart from the 3/2 power characteristic.

Any tube which gives the 3/2 power voltage-current curve must also give the straight-line when the volts and current are plotted on logarithmic paper. These two curves are plotted from the same data and their differences are due simply to the difference in the arrangement of the lines on the paper. If, therefore, the volts and currents be plotted on one kind of paper and the result shows a pure electron discharge, there can be no doubt what the other kind of paper would show. Certain counts, as 6 and 7, call for the straight-line, while count 8 calls for the 3/2 power characteristic.

Other counts refer to the electric field of the electrons (count 2) or to space current due to the electric field of the electrons (count 3). The electrons are supposed to be exceedingly minute pieces of negative electricity, and they react on one another just like a flock of pith balls would react if they were confined in some manner so that they were each within the field of influence of the others. If they were all charged with negative electricity and there were no available positive charge to neutralize them, they would simply create an electric field or space charge. But if at one part of this field a positive charge were created, the negatively charged pith balls would fly

across the field to it, thus setting up a current. That is what happens in the tubes of the issue. The electrons are generated or emitted by the heated cathode; and if there is no way of neutralizing them they simply fill the space, charge it negatively, and react on one another. But if the anode be charged positively, the electrons fly across the field to it and become neutralized. This flow of electrons is a current; and, assuming a sufficient emission of electrons, the strength of the current is dependent on the potential difference between the cathode and anode. If this difference is small, comparatively few electrons get through and the others continue to react on one another. If no gas be present in the tube, either free or occluded, the current is governed by the electric field of the electrons and the potential applied to the electrodes. If gas is present and the voltage is above ionization, some of the gas molecules become ionized and rendered positive by having one or more of their negatively charged electrons knocked out of place. These positively charged molecules or ions remain in the field a relatively long time and increase the flow of the electrons. This increases the current more rapidly than the pure electron current would increase and so deviates from the 3/2 power law. This explains the meaning of such counts as 2 to 5, inclusive.

The degree of ionization in a tube varies with the quantity of gas therein. Generally, when ionization occurs the current at a given voltage is larger than it would be at that voltage were no appreciable ionization present. If, therefore, a tube containing some gas were operated and the vacuum therein were gradually increased, as by a pump, the voltage remaining constant, the current would drop as the vacuum improved until ionization became substantially negligible, when the drop in current would cease. This is a test of the invention as defined in such counts as 2 and 3.

The character of the electron discharge is affected by the relation of the parts of the tube. When the

passage for the electrons is long, narrow or crooked, the electrons strike the walls of the tube and adhere thereto. This is exemplified by the Lilienfeld experiments in which a long, crooked, capillary-like tube was employed. Only a very minute current was obtained although thousands of volts were employed. Furthermore, it is not possible to remove all the gas, and, when the passage for the electrons is restricted, ionization takes place even in a very high vacuum. Such counts as 5, 8 and 9 call for such a "relation of parts" as render the tube capable of producing a current governed by the combined effect of the electric field of the electrons and the potential applied to the electrodes. Count 9 further states that the current is substantially unaffected by secondary electron emission from the walls of the tube. When the walls are long, crooked or narrowly spaced, the electrons adhere to them, as stated, until they are knocked loose by the electrons of the primary discharge. When thus set free, they constitute a secondary electron emission. The count further states that the current is substantially independent of the cathode temperature. According to Richardson's Law, which is extensively discussed in the records, the electron emission from the cathode increases with the temperature of the latter. But the number passing to the anode, in a tube of the issue, depends upon the impressed voltages. If at a given cathode temperature there are sufficient electrons to furnish the current at the voltage used, an increase of temperature and an increase of electron emission will not increase or otherwise affect the current. Under such conditions, the current is substantially independent of the cathode temperature.

Counts 12 and 13 are the only ones that call for the third electrode. This electrode is generally referred to as the "grid". It is placed between the cathode and anode; and when an electromotive force is applied to it, it modifies the electric field and controls the current passing to the anode. When there

is no ionization, this control is certain and the variations in the current follow proportionately and in a reproducible manner the variations of the electromotive force applied to the grid.

The invention in issue is, therefore, a thermionic tube that operates with a pure primary and substantially no secondary discharge at voltages above ionization and below saturation; and such a tube is to be recognized by its response to the characteristics expressed in the several counts. The tubes of counts 12 and 13 have three electrodes, while those of counts 1 to 11 may have two or more, these counts being generic.

The record on the motion and the accompanying exhibits were stipulated in for use on priority, and during 1921 and 1922, upwards of 300 additional pages of testimony were taken. Appeals were promptly taken in what seems to be an honest effort of the parties to hasten a final determination of the case.

The inventions and their development have taken place in the laboratories and shops of the Western Electric Company and the General Electric Company. The parties have had at their disposal unlimited aid, both personal and financial, for the development and investigation of the invention, as well as for the presentation of their cases here. This would lead us to hope and expect to find the issue clearly and simply presented for consideration. It seems, however, that both parties and their counsel have been overpowered with amazement at the abstruse scientific theories that may be evolved to account for the plain simple facts of operation of the invented device. The result is that we are presented here with 379 pages of brief by Langmuir, who has the favorable decision of the examiners-in-chief, and 281 pages by Arnold, in an endeavor, not to controvert that decision, but to show his own priority. Neither brief

pays much attention to the decisions below, but both attempt to treat the matter *de novo*, so that this decision may follow the same procedure.

The line between the prior art and the issue is attenuated and if there is patentability, it must be as set out in the decision of the law examiner on the motion, and I do not understand either party to attack that decision here. Arnold alleges that when he made the invention, he thought he was following the prior art and not producing something patentable, and an undercurrent of that attitude seems to tinge his whole case. This is why he filed so late.

I do not find it necessary to go beyond the decision of the law examiner to determine patentability or to interpret the prior art which was elaborately presented to him. He refers to:

Article by Fleming in Scientific American Sup., Jan. 20, 1906, p. 25, 129;

Article by Deininger in the Annalen der Physik, IV, Vol. XXV, p. 288 (1908);

Article by Von Baeyer, Physicalische Zeitschrift for 1909, p. 168;

Article by Gehrts, Annalen der Physik 39, p. 995 (1911);

Article by Child in the Physical Review, Vol. 32, p. 448 (1911);

Articles by Lilienfeld, Annalen der Physik 32, p. 673 (1910); Physicalische Zeitschrift 9, p. 193 (1908);

J. J. Thomson's Conduction of Electricity Through Gases, pp. 222 to 227;

Shottky, Jahrbuch der Radio Activitat, Vol. 12, p. 147 (1915);

Shottky, in Physikalische Zeitschrift, 15, 526 (1914).

After quoting freely from Langmuir's specification, he says:

> It is apparent after a review of the record that there is no single element which is broadly novel in the assemblage of elements making up an electron discharge device of the character defined in the issue. An evacuated tube having therein an incandescent electron-emitting cathode and an anode was old prior to the filing of Langmuir's application, and methods of attaining high vacua, sufficient to give a relatively pure electron discharge in a properly designed tube, were also well known and available to persons skilled in the art.
>
> * * * * * * * *
>
> The suggestion that the alleged invention represents a mere difference in degree over the prior art loses its force in the presence of the results accomplished (Edison *v.* U. S. Co., 52 F. R. 300, 308; General Electric Co. *v.* Nitro Tungsten Lamp Co., 282 O. G., 195), and the allegation of no invention is overcome by the presumption of invention in the transformation of laboratory experiments, and erratic and unstable devices into reliable, stable and successful commercial products (Marconi *v.* De Forest, 243 F. R. 560).

It will be seen then that the present invention lies not in discovering or producing something new, but in perceiving the practicability of scientific facts known in the laboratory and in making practical useful devices embodying the scientific laws known in the laboratory.

I am struck throughout the record with the care, caution and integrity of the parties and the witnesses. The effort seems to be constantly present to be scrupulously accurate and truthful. The benefits of this are largely lost by the fact that much of the record is made up of sworn statements followed by very little cross examination, some of which is by similar statements made not in the presence of opposing counsel.

Arnold claims conception of the invention "on or about Nov. 1, 1912."

Langmuir's original preliminary statement alleged conception of the invention "all during the month of November, 1912," but when the office objected to that he filed a new statement alleging: "the first device embodying the invention set forth in the issue of the interference was conceived * * * between the middle of the month of July, 1912, and the first day of September, 1912." We will see that his attorneys claim for him conception of the invention in August, 1912, but he meant what he said—not conception of the invention but conception (unperceived) of a structure embodying the invention, but for which he perceived no practical use.

As early as 1884, Thomas A. Edison discovered that in an evacuated incandescent lamp the current did not all go through the filament, but a portion leaked by jumping through the vacuum from one leg of the filament to the other leg. This was referred to as "Edison Current" and now is known as electronic discharge. In 1912, Langmuir was a recognized authority on incandescent lamps and was working in his laboratory on various tungsten lamp problems. In July, 1912, he asked an assistant Sweetser, to do certain experimenting for him. It was known that Edison Current tended to improve the vacuum in a lamp by clean-

ing up the remaining traces of gas. Of his work between July 20 and September 13, 1912, Sweetser says:

> • • • the primary interest in this experiment was the "clean up." The electron current was observed according to the general purpose of the experiment to determine its effect on the "clean up." As nearly as I can make out from the records, the purpose of the experiment is not to include a study of Edison current except as connected with the "clean up." (Langmuir Record on Motion, p. 734.)

During these operations some peculiar characteristics of the Edison Current were observed and it is alleged by Langmuir's attorney that this was a reduction to practice of the invention, and the examiners-in-chief say it was a conception of the invention. It does not appear that what was done then was of any practical effect in the manufacture of incandescent lamps. The most that Langmuir can say in 1919 is:

> (7) During August, 1912, we made experiments with lower gas pressures, using in many cases initial pressures of about 5 microns of nitrogen, and usually employing 200 to 250 volts on the anode. Under these conditions the residual nitrogen gradually disappeared, and in those cases in which the cathode temperature was rather high, the final pressure obtained was of the order of .3 microns. Before this lowest pressure was obtained, the character of the discharge changed completely, and from the results recorded, and by comparison with experiments subsequently made (November and December, 1912), I can now recognize clearly that with this new type of discharge we actually had a device in which the current was limited by space charge, substantially independently of positive ionisation, at voltages as high as 250 volts. (Langmuir Record on Motion, p. 546.)

But the law examiner held the space charge effect to have been recognized in the prior art. So that by these experiments Langmuir was doing nothing new and adding nothing to the sum of human knowledge. He had neither conceived the invention nor reduced it to practice. It is easy to see why the peculiar words were chosen for use in his preliminary statement.

Langmuir's interest was still paramount in incandescent lamps and he continued looking at Edison Current from that aspect. In November, 1912, he proceeded to experiment with other lamps "exhausted in the regular way that tungsten lamps were exhausted." These lamps had a long filament with four separate leads dividing it into three loops. Sufficient current was applied to the middle loop to burn it out and experiments were performed with Edison Current between the remaining loops. Very elaborate notes are introduced with reference to all these experiments, but there is doubt as to why the middle filament was burnt out. The notes say to separate the other two; the testimony says for that purpose and also to effect "clean up" in the bulb. Probably the latter is true, as such a clean up was not new. Work with this bulb surprised Langmuir by showing some of the effects of pure electronic discharge. He testifies his purpose was "to get an understanding of the fundamental laws involved, and thus *settle once for all whether or not* pure electron currents could be obtained in a practically perfect vacuum." This statement shows clearly that Langmuir had not made the invention before he started the November experiments. There is controversy as to what these experiments proved, but it seems clear that they produced nothing practical. Langmuir was still involved mentally with tungsten illuminating lamps and his report was to a group at the General Electric Laboratory which held weekly "conferences on matters relating to lamps" known

as the Lamp Vacuum Committee. The minutes under date of November 21, 1912, show that Langmuir reported his results and then did not insist on a high vacuum, but thought his effect was produced by gas present. "A plausible hypothesis to account for some of these effects is that a small amount of some gas such as argon always remains in the lamp." He makes no suggestion of practical use of what he has discovered. He is merely an experimental scientist traveling the road the prior art considered by the law examiner had already traveled—of course unknown to Langmuir. He says that "after November, 1912, steps were immediately taken to develop applications of this pure electron discharge" (Langmuir Priority Record, p. 120), but the first date I find in the record is December 10, 1912, when Langmuir writes in his notebook what to him indicates that he has suggested to Coolidge that his experiments might have a practical bearing on X-ray tubes. The lower tribunals have rightly refused Langmuir any benefit of the work of Coolidge, because Coolidge was not called to testify. But even if benefit be given, the first date of thought of practical use is December 10, 1912, and Langmuir can have no date of conception prior to this, since the law examiner has held that the invention lies not in laboratory experiments such as Langmuir had performed, but in commercial products. It was even later than this that he learned of De Forests's work with the audion. We need not go further with Langmuir's activities.

On October 30 and 31, 1912, De Forest brought one of his audions to the Western Electric Company and suggested its use as a telephone repeater. It was installed on an experimental telephone line and operated feebly for low sounds which produced small currents.

Prior to this time, Dr. Arnold had been employed by the Western Electric Company to work on telephone re-

peaters. He was recently from college where he had specialized in the physics relating to electric arcs between metal electrodes at various gas pressures. He had subsequently done graduate work along the same lines and as a part of this work had examined all available prior art literature. His entire life work was along the lines of electronic discharges. The De Forest audion was a device of this character and when the Western Electric people saw that it was not sufficiently useful for their purposes, they called in Arnold and on November 1, 1912, showed him the device in the experimental telephone line. Arnold testifies on pages 12 *et seq.* of Arnold's Priority Record, that on November 1, 1912, he explained that if the De Forest audion were further evacuated so that there would be in it only a pure electronic discharge not interfered with by ionization of the residual gas, the device would answer the purposes of the Western Electric Co. as a telephone repeater. This is confirmed by Colpitts and the other witnesses, they having been sufficiently informed of scientific facts to understand Arnold's suggestion. Arnold was thus able to make a practical or commercial application of the prior art laboratory knowledge. I agree with the examiners-in-chief where they say:

> According to this testimony, Arnold had a conception of a thermionic tube so thoroughly evacuated that it would have a pure electron discharge; and if it clearly appears that he knew how to produce such a tube, we would consider him entitled to November 1, 1912, for conception of the invention in issue.

Further, I am satisfied that Arnold knew how to produce such a tube. The law examiner says of the prior art "methods of attaining high vacua, sufficient to give a relatively pure electron discharge in a properly designed tube, were also known and available to persons skilled in the

art." Arnold had worked in this specific art for years and it seems unreasonable to believe he did not know how to produce the vacuum. The testimony is that he did. We have seen that Langmuir relies on the four lead tubes as a reduction and they were "exhausted in the regular way that tungsten lamps were exhausted," which seems to indicate that a novel exhaust was not necessary.

Langmuir in his brief here says:

> The important thing is to get a proper preparation of the tube and its parts; the method by which this is done is not important so far as the issues of this interference are concerned, so long as the result is achieved.

The Langmuir specification describes the device as prepared by evacuation, heat treatment of the glass tube, and heat treatment of the electrodes to eliminate occluded gases. (See also White's Answer to Q. 16, Langmuir Record on Motion, p. 601.) Arnold had developed an "arc repeater" filled with mercury vapor and had found that other vapors interfered with the work. He had therefore had to resort to heating the glass tube and heating the electrodes to eliminate gases other than mercury. At his University laboratory he had been familiar with means for producing high vacua, but the laboratory of the Western Electric Co. had not such means. He looked about and could not find what he wanted in New York and finally ordered by cable from Germany the very vacuum pump recommended in Langmuir's specification. When it arrived he produced tubes which operated practically and the subsequent commercial operations of his company are admittedly reductions to practice. By means of Arnold's devices the first telephone message from New York to San Francisco was sent and the first trans-Atlantic wireless telephone operated.

After Arnold's disclosure on November 1, 1912, any one skilled, as he was, in the art could have produced the device of the issue. If I say a rubber button is a good thing to use in a hose supporter, I have conceived the button, even if I do not know how to make such a button. I may go to a rubber manufacturer and have him reduce my invention to practice and it will be my invention. So here, one skilled in the art could produce the device in issue as soon as told to do so by Arnold.

> He who first conceives and gives expression to the idea of an invention in such clear and intelligent manner that a person skilled in the business could construct the thing, is entitled to a patent, provided he uses reasonable diligence in perfecting it. (McCormick Harvesting Machine Co. *v.* Minneapolis Harvester Works, 42 Fed. Rep., 152, 155.)

Here, the law examiner has held that the prior art taught him to get the required vacuum.

Before the pump arrived Arnold studied the characteristics of De Forest's audions at voltages below those of the issue and he found that one of these had a particularly effective high vacuum and it was successfully operated at voltages which are within the issue, but it is not necessary to hold it a reduction to practice as, in view of all the circumstances, the activities leading up to commercial use are sufficient to negative any lack of diligence on the part of Arnold.

Langmuir objects because Arnold did not proceed at once to use makeshifts to produce the proper vacuum in many bulbs, but I think he was justified in awaiting the arrival of the pump from Germany, especially since he studied the characteristics of what he had and started his associates preparing themselves for the work and did proceed soon after the arrival of the pump.

Adverse comment is made on Arnold's study of the De Forest audion after he says he made the present invention, but that is just what Langmuir had White do in February, 1913 (Langmuir Record on Motion, p. 599, Q. 14).

The condition of the negotiations for patent licenses from Cooper Hewitt and from De Forest sufficiently account for the activities with the "arc repeater".

I have carefully examined the records and tried to weigh every point raised by the arguments or elaborate briefs, but it is impossible to state in an opinion every consideration going to fix a conclusion in the mind.

What I have said shows that Arnold was first to conceive and proceeded diligently to reduce the invention of all the counts, including 12 and 13, which call for a third electrode which Langmuir did not deal with until 1913.

The examiners-in-chief are reversed and priority awarded to Arnold.

KARL FENNING,
Assistant Commissioner.

October 27, 1923.

FILE COPY

FILED
JAN 30 193
CHARLES ELMORE CR
CL

IN THE

SUPREME COURT OF THE UNITED STATES

OCTOBER TERM, 1930

No. 630

DEFOREST RADIO COMPANY

Petitioner

v.

GENERAL ELECTRIC COMPANY

Respondent

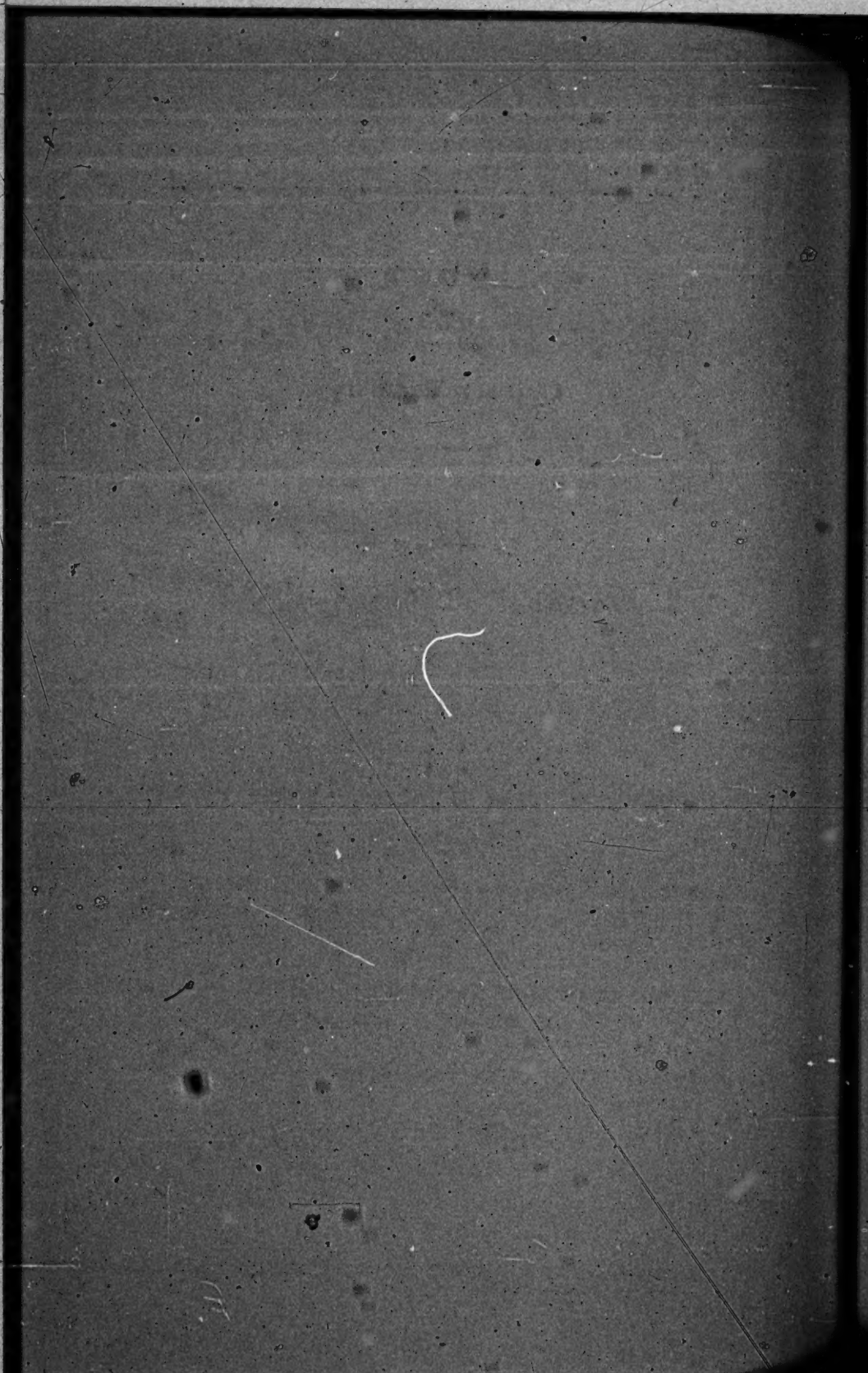
OPINIONS

OF THE UNITED STATES CIRCUIT COURT OF APPEALS, THIRD CIRCUIT, OCTOBER 3, 1929, AND NOVEMBER 11, 1930,

AND

OF THE COURT OF APPEALS OF THE DISTRICT OF COLUMBIA IN ARNOLD *v.* LANGMUIR

JUDAH PRINTING CO., 32 FRANKS ST., NEW YORK CITY



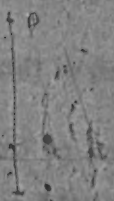
INDEX

PAGE

The Memorandum Decision of the U. S. C. C. A., 3rd Circuit, October 3, 1929 1

Opinion of that Court, November 11, 1930 2

Opinion of Court of Appeals, D. C., in Interference, Arnold *v.* Langmuir 19



IN THE

United States Circuit Court of Appeals

FOR THE THIRD CIRCUIT.

GENERAL ELECTRIC COMPANY,
Appellant,

v.

THE DEFOREST RADIO COMPANY,
Appellee.

No. 3799.
March Term,
1928.

APPEAL FROM THE DISTRICT COURT OF THE UNITED STATES FOR THE DISTRICT OF DELAWARE.

(Filed October 3, 1929.)

Before BUFFINGTON, WOOLLEY and DAVIS, *Circuit Judges.*

Per Curiam.

The issues raised on these appeals were fully discussed in the opinion of the learned district judge and we agree with his conclusions. The decrees are, accordingly, affirmed on his opinion.

BUFFINGTON, *Circuit Judge*, dissents.

IN THE

UNITED STATES CIRCUIT COURT OF APPEALS,

FOR THE THIRD CIRCUIT.

GENERAL ELECTRIC COMPANY,
Appellant,

v.

THE DEFOREST RADIO COMPANY,
Appellee.

No. 3799.
March Term, 1928.

APPEAL FROM THE DISTRICT COURT OF THE UNITED STATES FOR THE DISTRICT OF DELAWARE.

Opinion of the Court.

(Filed November 11, 1930.)

Before BUFFINGTON, WOOLLEY and DAVIS, *Circuit Judges.*

BUFFINGTON, *J.*

In the Court below the General Electric Company charged the DeForest Radio Company with the infringement of four patents. On final hearing that Court held one of the patents valid and infringed and the other three invalid. By appropriate steps its so holding was brought before this Court for review. Without entering into detail, we may say that, save as to patent No. 1,558,436, the reasoning, conclusion and decree of the

Court below commend themselves to us and we affirm the same. In the case of patent No. 1,558,436, we feel the Court below committed error in holding the patent invalid and dismissing the bill.

As usual in litigation over a patent of great commercial value, the vast mass of expert speculation, the protracted argument covering days and with briefs that in the aggregate covered several hundred pages, the case, on re-argument, narrowed to the simple question of the patent paternity of what is known commercially as the Langmuir tube. The Court below held the tube had no patent paternity and to that question we now address ourselves. The subject-matter of the patent and the general features of the pertinent art are set forth at length in the comprehensive opinion of the Judge below and by reference thereto we avoid the necessity of present restatement.

Laying aside for the present technical language and scientific discussion and confining ourselves to simple statement, the Langmuir tube is a tube in which for example the gaseous conductor incident to a Fleming valve and a DeForest audion is dispensed with and a vacuum substituted therefor.

In the patent sued on, No. 1,558,436, granted October 20, 1925, to Irving Langmuir, assignor to the General Electric Company for "electrical discharge apparatus and process of preparing and using the same," the specification states:

> "The present invention relates to electrical *vacuum* discharge devices, and it comprises devices in which the electrical current is carried by negative charges called electrons, emanating from the cathode, independently of *gaseous ionization* such as occurring, for example, in the ordinary Roentgen tube.

"My present invention comprises improvements in electron-discharge apparatus which make possible a *high load capacity* and operation with the *highest voltages*, but the invention is also applicable and useful for moderate loads and moderate voltages."

Existing objectionable incidents to the use of gassy tubes and the erratic, non-determinable action of gas are pointed out as follows:

"In order to distinguish electron discharge devices made in accordance with my invention from the prior art, I will explain briefly the character of a *pure electron* discharge as distinguished from a discharge through *ionized gas*. In a Geissler tube, and in a Roentgen or Crookes tube the conduction of current is accompanied by and depends upon *gas ionization*. Without a certain *minimum amount of gas* a Roentgen X-ray tube ceases to operate and as this minimum is approached the resistance of the tube steadily increases.

"The passage of an electric current across a tube ordinarily involves the movement of negative charges called electrons which, under the influence of the impressed voltage, pass from the cathode to the anode through the *vacuous space*. If these electrons when moving above a certain velocity collide with *gas molecules* they tend to ionize the molecules, splitting them up into electrons and larger and more slowly moving ions. Under these circumstances the phenomena of conduction across the tubes are the result of the action and interaction of the electrons and the ions; these phenomena are in general *erratic and non-reproducible*. The cathode under these conditions is disintegrated, technically it is 'sputtered', which causes its rapid destruction. As *gas ionization* continues at higher voltages a *blue glow* may appear. The bombardment of the cathode by positive ions also

causes heating of the cathode. The ionization of gases at low pressures by collision with electrons occurs at definitely determinable voltages, these voltages being known as the ionization voltages. *These voltages are different for different gases.* In the case of gases such as nitrogen, hydrogen, oxygen, argon, helium and neon, they are of the order of magnitude of fifteen to twenty-five volts."

Describing the DeForest audion and differentiating it from the alleged invention of the patent, the specification says:

"The phenomena above described as being characteristic of devices involving *gas ionization* are taken advantage of in an incandescent cathode device with three electrodes known as the 'Audion.' This device has been used as a receiver for radiotelegraphy and depends in its operation upon the rapid change of the discharge current when *gas ionization begins.* This point depends upon various *accidental* conditions which cause such irregularities in the operation of various devices apparently identical that sometimes only one of a considerable number can be used. Ordinarily the gas ionization in the audion begins to be important somewhere between 20 and 30 volts."

Describing the Fleming valve and its limitations, the specification states:

"Another discharge device previously used to some extent was the *Fleming valve.* This was a two-electrode tube which, so far as I am aware, was always used at voltages well below the voltages at which positive ionization by collision occurs. It was not evacuated in such a manner as to permit it to be used at voltages materially above these ionization voltages without manifesting substantial positive ionization effects."

Referring to high voltage, the specification makes this statement:

> "No prior hot cathode devices are known to me operating with currents as great as above 5 milliamperes with voltages as high as about 200 volts; indeed no prior discharge devices are known to me operating in a practically usable manner and without substantial positive ionization effects with currents as great as about one-tenth of a milliampere with voltages as high as about forty volts."

Specifying some of the differences and advantages of the alleged invention, the specification states:

> "In devices made in accordance with my invention *gas ionization* is either entirely *absent* or is negligible and a discharge takes place which is *distinct* in its characteristics from the described discharge taking place in an *ionized gas*. The cathode is not heated by the discharge itself. Blue glow, glass fluorescence and in fact all readily visible indications of a discharge are ordinarily absent."

Referring to the evacuation of the tube, the specification sets forth:

> "For the evacuation of the device the glass walls of the tube are carefully heated to as high a temperature as the glass will stand without softening and in general the most approved methods of incandescent lamp exhaust are used. The evacuation of the tube preferably while still heated is carried out by means of a suitable evacuating means, for example, a Gaede molecular pump, which removes *vapors as well as gases* * * *
>
> "The evacuation of the device should be preferably carried to a pressure as low as a few hundredths of a micron, or even lower, but no definite limits can be assigned. * * *

"It is also true that when the anode has been carefully freed from gas, residual free gas, even if present in a sufficient amount to cause some gas ionization when the apparatus is first started, does little harm, as it is quickly removed by the gas clean-up effect when the device is operated."

Claim 12, which is,

"An electrical discharge device, comprising a gas-tight-envelope, an electronemitting cathode, an anode *deprived of ionizable gas* and a discharge controlling conductor, the space in the envelope being evacuated to a pressure not substantially in excess of a few hundred thousandths of a millimeter of mercury, said device being characterized by the fact that when operated below saturation and materially above the ionization voltages, the current is controlled by *space charge* substantially unaffected by positive ionization."

is typical in character of the alleged invention.

Does the defendant use a tube answering this general description? We think it does and that in giving up the old gaseous tube and using one of the "very high vacuum," a change which it announced in its statements to the public, we have a virtual admission of the essential difference between the two tubes. The tube of this disclosure is aptly described as "non gaseous" and "of a very high vacuum" by the defendant when putting it on the market, as follows:

"The tube consists of a highly evacuated vessel, cylindrical, rather than bulbular, in shape enclosing the three elements, grid, plate and filament in the form of the old type T tubular DeForest tube with which amateurs are familiar. The plate is of nickel, cylindrical in shape and surrounds a helical grid also of nickel. The filament is a crimped tungsten wire passing through the center of the

grid exactly as it did in the old style type DeForest tube. The chief difference between this tube and the type T tube of similar mechanical construction is in its evacuation. The old style type T was an *ionic or gaseous tube* very unstable in operation and requiring a variable 'B' battery. It had the decided disadvantage that after continued use the tube would get 'hard' and require more 'B' battery until it reached such a state as to be inoperative. The new 'VT' tube, like the DeForest standard tubes to-day, is purely an electronic tube exhausted to a *very high vacuum*, so that it is non-gaseous and will stand very high plate potentials. When used as a detector, however, a battery of 20 to 40 volts is sufficient to give the proper plate current although voltages of 80 to 100 may be used without detrimental effect upon the tube. The 'B' battery moreover, is not critical in adjustment and, therefore, a fixed battery may be used and is used for all practical work. * * * The gaseous type tubes are, however, no longer being manufactured."

Turning next to the question on which the validity of the patent depends, we inquire first as to its usefulness, for the constitutional power to create the monopoly of a patent in that regard conditioned "to promote the progress of * * * useful arts" and the Congressional enactment in pursuance of the Constitution is that "any person who has * * * discovered any new and useful" etc. For in the final analysis, use, usefulness, is the acid test, the SINE QUA NON of patent grant.

The unusual degree of usefulness of the tube may be assumed. The defendant by its use evidences its usefulness and has, we have seen, adopted it and ceased making "gaseous type tubes," and the Court below, after its exhaustive study of the art, aptly described the tube, and we agree with its estimate, as an agency which "because

of its stability, reproducibility and power has made possible radio broadcasting, modern radio reception and long distance telephony."

Seeing then we are here dealing with a progressive step which next to the telegraph, the telephone and the wireless, is probably one of the most far reaching and beneficent in human progress, there can be no question of a non-gaseous, vacuum tube's usefulness. Such being the case, is it novel? The simple fact is that we see such a tube in universal use to-day; we know in the quoted language of the Court below of its "stability"; of its "reproducibility"; of its "power." We know that these elements have, as stated by the Court below, made "possible radio broadcasting, modern radio reception and long distance telephony." Indeed the fact that a non-gaseous vacuum tube makes possible the present improved practice shows that such practice did not exist before the Langmuir tube and that no other device or devices, all important as they may have been in their spheres, did either singly or collectively produce the present practice. The patent office recognized that. In the opinion of The Board of Examiners they found, in affirming the decision of the Examiner of Interferences, that "Langmuir was the first to conceive and the first to reduce."

While all the vast mass of knowledge testified to in these records was open to everyone to use, the simple fact remains that the non-gaseous tube of modern use did not occur to scientists. Every one of the two hundred and sixty-six words in Lincoln's Gettysburg Speech is found in the dictionary; most of them in the Bible. But it remained—not for Noah Webster or even the Prophets of old—but for Abraham Lincoln to take these isolated words and so use them conjointly as to produce the most remarkable combination in literature.

We do not disregard or minimize the all important part of DeForest's audion and Fleming's valve play in the utilization of them in the Langmuir tube, but in spite of such high value, neither of them, in isolation or conjoint use, gave the world the tube here in question and it remained for Langmuir to so couple and coordinate the two by means of eliminating gas and using vacuum as to produce the tube here involved. What scientific credit is due to DeForest or Langmuir or to what patent tribute Langmuir subjected himself in thus using their devices are questions not before us.

Moreover the statement in the Commercial Circular of the DeForest Company that gas was an element of operation, was in accord with the then scientific belief. In 1911 Gernsback, an experienced savant, wrote that in the audion "the operating principle is the shattering of a column of conducting gas by a received electrical impulse."

The function of a gaseous tube as a conductor was stated by the Circuit Court of Appeals of the Second Circuit in 243 Fed. Rep. 565, where Fleming's valve and DeForest's audion were considered, in these words: "The 'gaseous medium' of the audion is nothing but the commercial vacuum of the ordinary electric light bulb—air being a gas, and the bulb containing some residual air. In other words, defendant uses the same 'vacuous vessel' that Fleming does." And in its opinion it stated that it was asserted in that case that the audion was "an apparatus in which the bulb contains a substantial amount of gaseous medium essential to the operation of the device." To the same effect is the testimony of Langmuir, of which we find no contradiction, that

> "In the devices of the old art, in the DeForest audion, the pressure was continually changing. It

sometimes increased and it sometimes decreased. Both things went on and there was an evolution of gas, water vapor would come off the bulb and be decomposed by the filament and it would generate gas. Gases would come out of the electrodes. Positive ions would bombard the walls and the electrodes and would drive gas off."

It will also be noted this Court in its able and exhaustive statement of the art in 21 Fed. (2) 918, said: "We observe that at the time of both the DeForest and the Armstrong inventions the only audion tubes in use were 'gassy' or 'soft'."

That its action was eccentric, is shown by DeForest's statement:

> "In the first place, anyone who has had considerable experience with numerous audion bulbs must admit that the behavior of different bulbs varies in many particulars, and to an astonishing degree. The wing potential wing current curves for different bulbs, or even for the same bulb at different times, under different conditions (filament temperature, etc.) vary widely.
>
> "What may appear to be a fixed law for one bulb may not hold for another."

On the other hand, the current in Langmuir is practicable, steady, reproducible at any particular voltage.

It further appears that the Langmuir tube has a great advantage when it comes to replacement. When a tube is defective, another of the same type can be bought and placed in the same socket. Not so with the audion. It required frequent replacement and where replacements were made it was necessary to readjust throughout the circuit. In that respect the proof is:

"XQ35. What practical effect would harmful ionization have upon an audion amplifier such as, for example, as is used in the telephone line?

"A. The worst immediate effect would be as to uniformity of operation, which would make continued adjustments necessary and would interfere with the replacement of one device by another, that is to say, when one tube burned out and another were put in an amount of ionization that would interfere with uniformity of operation would make it necessary to readjust throughout the circuit to take care of the substitute tube."

As to the replacement, the proof is that

"Another consequence of this uniformity is that replacement of the tubes without changing the apparatus becomes possible. That is particularly important in telephone repeaters and in radio devices both of the receiving and transmitting type. One wants to know that he can replace a burned-out tube with a new tube without having to make substantial changes in the apparatus."

It will also be noted that the whole trend of the art was against the use of a vacuum, and even after Langmuir had shown its use, it was deemed impractical. Thus in a paper of 1914 Wehnelt and Leibreich said that ionization persisted in the best vacuum they could get.

Moreover, it is of great present significance that the then view of DeForest himself was against Langmuir's use of the vacuum, he then stating in a paper read by him before a scientific body: "I believe, however, Dr. Langmuir has, by working into these high vacua and the high potentials necessitated thereby, pursued the less promising of the two paths of research." The record shows no explanation, comment or retraction by him of this statement.

Such being the general state of the case, has the defendant by evidence overcome the prima facies of the patent? We think not. As said by this Court in 159 Fed. Rep. 948, citing the Barbed Wire Case, "the burden of proof upon this part of the case rests upon the defendant, and every reasonable doubt should be resolved against it." And in our view the crux of the case is one of fact, namely, whether the use of a vacuum in the combination of the claim was Langmuir's novel disclosure. We are not concerned with scientific theories and speculations as to what might have been done or what could possibly have been done for, as well said by the Circuit Court of Appeals of the Second Circuit in 298 Fed. Rep. 582, we sit "not as scientists, but as weighers of evidence." But we are concerned with the fact whether the combination of the claim which Langmuir disclosed was new. That some had bombarded anodes of X-ray tubes to get some of the gas out of them; that others had heated bulbs or used pumps to lessen the gas, may all be true, but none of them had produced the commercial tube which Langmuir gave to the public. And such actual contribution in use and not theory and possibility of speculation is, and of right should be, the decisive factor in patent reward. As was said by the Circuit Court of Appeals of the Second Circuit:

> "The keynote of all the decisions is the exent of the benefit conferred upon mankind. Where the court has determined that this benefit is valuable and extensive it will, we think, be difficult to find a well considered case where the patent has been overthrown on the ground of non-patentability."

We regard as of high evidential significance the statements made by the defendant in its circular to the public, already quoted. It will not do to brush aside and

ignore it on the suggestion it was the work of some enthusiastic subordinate or sales agent. It was a deliberate statement of a great mechanical company of its ceasing to make and market a superseded article and to thereafter make and market a new and different one. No such change would in business practice be made by subordinates, but was, in the nature of things, the mechanical, scientific and commercial determination of a great business organization. In this statement the defendant recognized a "non-gaseous," highly vacuum tube as new. As we have seen, it differentiated it from its "gaseous" tubes up to then made and publicly announced that such gaseous type tubes would no longer be manufactured. And indeed, that no such non-gaseous, highly vacuum tube existed is shown by the fact that the testimony of experts and the laborious research by the Judge below, whose industry is proverbial, did not disclose any such tube as both parties to this litigation now make and contend for the right to make, existed or had advanced the arts in question to this new standard of theretofore non-attained efficiency.

Such being the case, the defendant is driven to take the position—which found favor with the Court below—that in view of what existed in the prior art, that it required no invention to so utilize these things in the prior art to produce a non-gaseous, highly vacuum tube, and that this great progressive step was due simply to the art's natural advance and improvement.

But in point of fact no such advance toward a non-gaseous tube, as we are now told was to be looked for in the art, was actually made by the art. We would not be misunderstood. Advance, inventive and non-inventive, was being made in the art, but their efforts were in other directions. We would not detract from the great

advance made by DeForest and exemplified by his audion and by Fleming with his valve, but great as these steps were—both separately and collectively—and we regard them as the foremost in the advance of the art in the sphere here involved—the gaseous tubes still continued to be used and the art generally regarded gas as incident, if not, indeed, indispensable to their use.

Indeed, had the art followed the caution of DeForest heretofore quoted, we would have no vacuum tube, a situation akin to that referred to by this Court in the Turbine case, 202 Fed. Rep. 932, where we said:

> "Finding, then, as we do, that the disclosures of the Moorehouse patent had no helpful bearing or practical effect on the impulse turbine art, and supported in that conclusion by the fact that its vagueness is such that fair-minded witnesses in this record greatly differ as to what its disclosures really are, we are not warranted in attributing to it any effect in the way of vitiating, or even minimizing, the work of Curtis."

Now as it seems to us, the art, although it did not exactly know how the gas in gaseous tubes acted and just why it was able to so conduct, nevertheless continued to use it and regarded it as the indispensable means of conducting. As against this firmly entrenched teaching and practice of the art, Langmuir's suggestion of eliminating gas as a conductor was a radical change and even more so was not the substitution of some other tangible conductor, but the disclosure of supplanting the tangible gaseous conductor by the intangible conductor of a vacuum. Vacuums, per se, were of course known. DeForest's audion and Fleming's valve were equally known, but the suggestion of dispensing with gas and utilizing a vacuum between the two was as novel in practice as it was unlooked for in result. Indeed, shortly before the patent

in suit was applied for and even though the use of a vacuum may possibly have been suggested, the director of the Research Laboratory stated in a paper read before the American Institute of Engineers: "In connection with this work of Fleming's, we have studied the effect of vacuum on the current, and also found that the presence of gas is necessary for this negative discharge." And that Langmuir's use of high vacua did not appeal to so practical and eminent a scientist as DeForest was evidenced by his statement, heretofore quoted, made even after Langmuir had made known his process publicly,—"I believe, however, that Dr. Langmuir has, by working into these extremely high vacua and the high potentials necessitated thereby, pursued the less promising of two paths of research." For the defendant to now contend that the use of these extremely high vacua by Langmuir was simply the natural and to be expected growth of the art is to credit the ordinary art with a scientific capacity which a master of the art like DeForest did not himself possess. If it was an obvious thing, as the Court below believed and decided, for the ordinary art to do away with gas and gaseous tubes and substitute high vacua therefor, surely such an extraordinary mind in that art as DeForest, when confronted with the substitution, would not have pronounced high vacua a mistaken path. Had the ordinary art followed the advice of this super ordinary adviser and leader and discarded the suggestion of high vacua, it would seem so far as the universally used non-gaseous tube is concerned, it would not be in use today.

But it is contended by the defendant and the Court below so held, that all that Langmuir did was simply to vary in degree the prior use of the vacuum and that a mere difference in degree does not constitute invention or, to use the defendant's contention, the Langmuir tube

is "nothing more or less than the identical thing of the prior art with possibly a little higher vacuum, depending on the specific use to which the device is to be put." Assuming the correctness of this general proposition, we think it is not applicable to the present case. In considering change in degree, the test is not the quantum or minimum of change made but the quantum of change in function and result which such change, great or small, effects. A great change may effect but a slight change in function and result, while a slight change may effect a radical difference in function and effect. The effect, the practical progress and use in the arts, are the aim and end of patent grants and where great results follow a change, the slightness of the change tends to emphasize and make all the more remarkable, unexpected and inventive the disproportionate result the slight change effects. It was the slight turn of a screw and the closer proximity of the diaphram that made the telephone diaphram the carrier of speech and gave Bell the due reward—not for the slight turn of the screw but for the great effect it wrought. But a vacuum, or indeed change of vacuum, isolated and standing by itself, is not the Langmuir invention, but it is a working tube in which all the elements, cathode, plate, vacuum, so co-ordinate and interwork that current flow is not affected by gas. We say not affected by gas because of necessity an absolute vacuum is an impossibility, but the degree of vacuum is such the current flow is no longer objectionably affected by gas. Just what the degree of vacuum shall be is dependent on several elements and, as stated in the patent, cannot be exactly stated. In that regard the specification says: "The evacuation of the device should be preferably carried to a pressure as low as a few hundredths of a micron, or even lower, but no definite limits can be assigned."

So regarding what we believe to be the basic question in the case, we limit ourselves to the foregoing statement of our reasons for our conclusion. But in thus limiting our discussion, we deem it proper to say that the numerous questions and considerations advanced in the case in other particulars, have been duly considered.

The degree of the Court below holding this patent invalid is reversed and the record remitted with instructions to enter a decree that the patent is valid and infringed.

IN THE

COURT OF APPEALS

OF THE DISTRICT OF COLUMBIA.

IRVING LANGMUIR, *Appellant,* v. HAROLD D. ARNOLD.	No. 1680. Patent Appeal.

Opinion of the Court.

(Filed June 1, 1925)

(6 Fed. [2nd] 704)

(Before MARTIN, Chief Justice, and ROBB and VAN ORSDEL, Associate Justices)

Appeal from a decision of an Assistant Commissioner of Patents in an interference proceeding awarding priority to the junior party, Arnold, and reversing concurrent decisions of the Examiner of Interferences and the Board of Examiners-in-Chief.

The invention is a thermionic tube adapted to be used as a relay in long distance telephone systems, as a detector or amplifier in wireless systems, or as a rectifier of alternating currents. The issue is expressed in thirteen counts, of which the 1st, 7th and 13th, here reproduced, will serve as examples:

> "1. A high vacuum electron discharge device comprising an envelope, an incandescent cathode and an anode, the space in said envelope being evacuated to such degree that the passage of current produces no appreciable positive ionization when the impressed voltage is as high as 200 volts."

"7. A discharge device comprising a tube and electrodes therein one of which is adapted to emit electrons, the degree of evacuation and the relation of the parts of the device being such that the device is capable of being so operated, when voltages materially higher than ionization voltages are impressed on electrodes of the device and when the electron emission has any value such that the space current is below the saturation region at such voltage, that the line obtained by plotting the logarithms of any values of said current below the saturation region as ordinates against the logarithms of the corresponding values of said impressed voltages as abscissae is straight and continuous."

"13. The method of controlling an electric current in one circuit by an electromotive force in another circuit which consists in causing said current at voltages materially above ionization voltages to pass as a discharge across a vacuous space between an electron emitting cathode and an anode, maintaining a high vacuum in said space, governing or limiting the current by a space charge effect in said space substantially unaffected by positive ionization, and superimposing the effect of said electromotive force on said space charge effect to control said current in a stable and reproducible manner."

The attitude of the junior party, appellee here, when this interference was declared, is significant. He filed a motion challenging the patentability of the issue and sought and obtained permission to take evidence in support of that motion. The result was the taking of voluminous testimony by the parties on this issue, which by stipulation is in the record here. The Law Examiner, to whom this question was initially referred, sustained the patentability of the issue and his decision is controlling

here. We therefore start our inquiry in this appeal with the established fact that, so far as this proceeding is concerned, the issue is patentable; in other words, that something more than mere mechanical skill was involved in the result achieved.

The examiner of Interferences, in an exhaustive opinion, awarded priority to the senior party, Langmuir. The Board, on appeal, directed attention to the fact that, structually considered, the tubes of both parties outwardly are substantially identical with the Fleming valve and the DeForest audion of the prior art; that the invention has been referred to as a "thing compact of glass and metal". The Board then pointed out that this definition, although correct as far as it goes, is inadequate because it applies equally well to the prior art devices, and that to this definition should be added the qualification that the device "operates with a *pure* electronic discharge above the voltage of positive ionization and below saturation", and proceeded: "But how is one to know whether the discharge is purely electronic? In other words, how is one to know whether a tube embodies merely the prior art devices or the invention of the issue? * * * For example, count 1 specifies that the envelope of the tube is evacuated to such a degree that the passage of current produces no appreciable positive ionization when the impressed voltage is as high as 200 volts. Thus the count distinguishes from the prior art, not by features of structure, but by a characteristic which is manifest while the device is operating at or above a certain voltage."

Later in its decision the Board suggested that the question to be determined was, who of the parties "first knowingly and understandingly conceived and produced such a tube"; that Arnold, the junior party, did not claim to

have conceived the invention prior to November 1, 1912, or to have reduced it to practice prior to the 29th of that month; that Langmuir, on the other hand, alleged conception, disclosure, sketches, written description and successful operation prior to September 1, 1912, followed in November of that year by the successful operation of other devices embodying the invention. The Board then carefully reviewed the testimony in support of Langmuir's contentions and found that he had conceived the invention of counts 1 to 11, inclusive, as early as September 1, 1912, and had reduced the same to practice by November 19th of the same year; that, as to counts 12 and 13, Langmuir had conceived prior to April 8, 1913, and had reduced to practice by April 15th of that year; that Arnold conceived and reduced to practice the invention of all of the counts except counts 1 and 11 on April 25, 1913, and that counts 1 and 11 were not reduced to practice until after Langmuir's filing date.

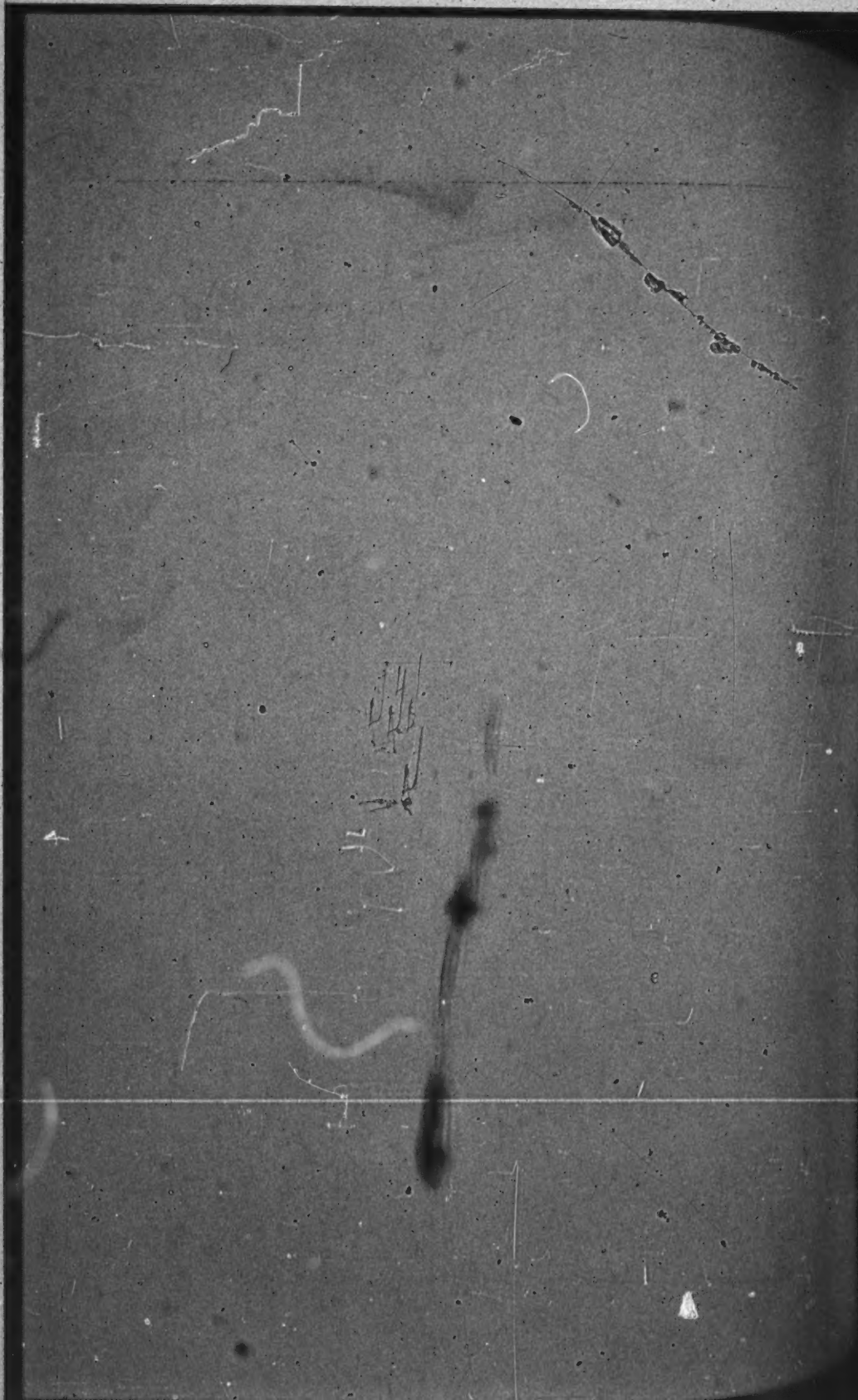
The attitude of the Assistant Commissioner toward the case was that of the junior party upon the declaration of the interference, namely, that the patentability of the issue was doubtful. He says: "The line between the prior art and the issue is attenuated and if there is patentability, it must be as set out in the decision of the Law Examiner on the motion, and I do not understand either party to attack that decision here. Arnold alleges that when he made the invention, he thought he was following the prior art and not producing something patentable, and an undercurrent of that attitude seems to tinge his whole case. This is why he filed so late." Proceeding from that prostulate, the Assistant Commissioner has accepted as controlling on the question of conception and reduction to practice, on behalf of Arnold, testimony of a vague and general character and which failed to satisfy

the lower tribunals, as it also has failed to satisfy us. The decisions of those tribunals are so clear and satisfying that we are content to rest our opinion upon the reasoning there given.

It results that the decision is reversed and priority awarded Langmuir.

Reversed.

CHAS. H. ROBB,
Associate Justice.



FILE COPY

Office Supreme Court,
FILED
APR 29 193
CHARLES ELMORE CR
CLE

IN THE

Supreme Court of the United States

No. 630 October Term, 1930

DEFOREST RADIO COMPANY
Petitioner

v.

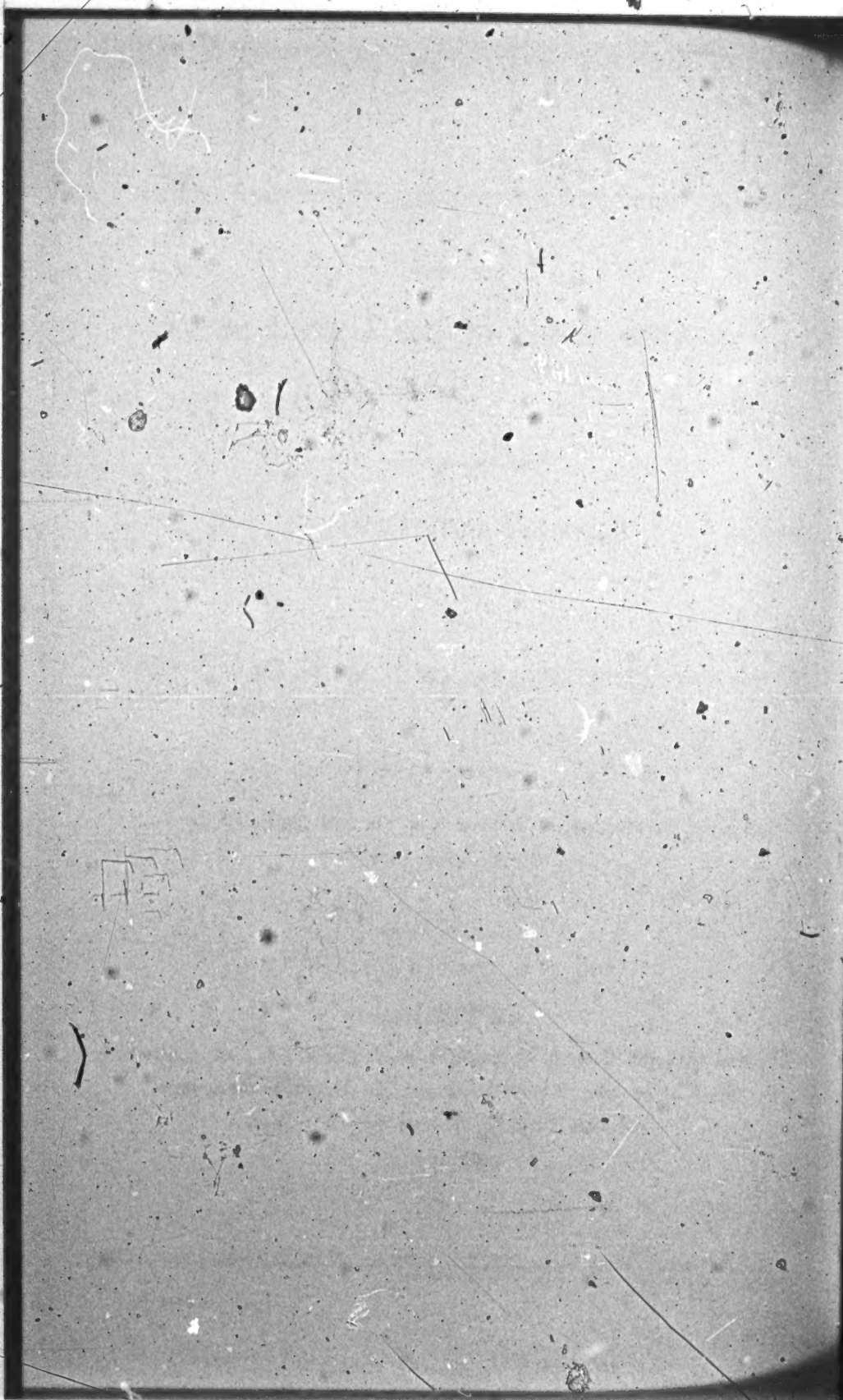
GENERAL ELECTRIC COMPANY
Respondent

ON WRIT OF CERTIORARI TO THE U. S. CIRCUIT COURT OF APPEALS
FOR THE THIRD CIRCUIT

OPINIONS

Of the Patent Office Tribunals and the Court of Appeals, D. C., in the Arnold-Langmuir Interference and of the Courts Below in This Suit

JUDD PRINTING CO., 32 THANES ST., NEW YORK CITY



INDEX

IN THE INTERFERENCE ARNOLD *v.* LANGMUIR.

	PAGE
Opinion of Law Examiner	1
Opinion of Interference Examiner	18
Opinion of Examiners-in-Chief	48
Opinion of Assistant Commissioner	72
Opinion of Court of Appeals, D. C.	91

IN THE SUIT OF GENERAL ELECTRIC CO. *v.* DEFOREST RADIO CO.

Opinion of Judge Morris, District Court	96
Memorandum of United States Circuit Court of Appeals	125
Opinion of United States Circuit Court of Appeals on Rehearing	126
Dissenting Opinion of Judge Woolley	143

Opinion of the Law Examiner.

February 21, 1921.

(Interference Record p. 2462.)

IN THE UNITED STATES PATENT OFFICE.

Patent Interference No. 40,380.

ARNOLD

v.

LANGMUIR.

Motion to Dissolve. Motion to Amend.

Electric Discharge Apparatus and the Process of Preparing the Same.

Application of Harold de Forest Arnold filed Nov. 2, 1915, No. 59,210.

Application of Irving Langmuir filed March 14, 1916, No. 84,242, renewal of application filed October 16, 1913.

Messrs. DE WITT C. TANNER and JOHN G. ROBERTS and MR. GEORGE E. FOLK for Arnold.

MR. ALBERT G. DAVIS for Langmuir.

The party Arnold moves to dissolve on three grounds which are as follows:

1. That there has been such informality in declaring the interference as will preclude the proper determination of the question of priority of invention.

2. That the party Langmuir has no right to make the claims constituting counts 1, 2, 3 and 7 of the issue of the interference, and hence that the claims are not patentable to him, even if they involve patentable subject matter.

3. That the claims constituting the counts are not patentable to either party.

The first ground will be treated as stating that neither party can make the claims. A supplemental motion to dissolve by Arnold includes additional references which are as follows:

Article by Fleming in Scientific American Sup., Jan. 20, 1906, p. 25,129;

Article by Dininger in the Annalen der Physik, IV, Vol. XXV, p. 288 (1908);

Article by Von Baeyer, Physicalische Zeitschrift for 1909, p. 168;

Article by Gehrts, Annalen der Physik 39, p. 995 (1911);

Article by Child in the Physical Review, Vol. 32, p. 448 (1911);

Articles by Lilienfeld, Annalen der Physik 32, p. 673 (1910); Physikalische Zeitschrift 9, p. 193 (1908);

J. J. Thomson's Conduction of Electricity Through Gases, pp. 222 to 227;

Shottky, Jahrbuch der Radio Activitat, Vol. 12, p. 147 (1915);

Shottky in Physikalische Zeitschrift, 15, 526, (1914).

The procedure in the present contest is exceptional in that a petition for leave to take testimony on the motion to dissolve was granted by the Commissioner on Feb. 23, 1917.

Langmuir moved on Jan. 29, 1917, to amend the issue to include claims 24 to 28 as counts, and subsequently, on May 19, 1919, moved to amend by including claims 1 to 9, inclusive.

After the hearing Langmuir withdrew counts 1, 2, 3, 4, 6 and 7 and claims 24, 25, 27 and 28, leaving for consideration count 5, claim 26 and claims 1 to 9, inclusive. The motion to dissolve is granted as to counts 1, 2, 3, 4, 6 and 7, and the motions to amend are denied as to claims 24, 25, 27 and 28. Count 5, claim 26, and claims 1 to 9, inclusive, which have been retained, are as follows:

Count 5. A high vacuum electron discharge device comprising an envelope, an incandescent cathode, and an anode, the space in said envelope being evacuated to such degree that the passage of current produces no appreciable positive ionization when the impressed voltage is as high as 200 volts.

Claim 26. An electrical device comprising the combination of a sealed evacuated envelope, a cathode adapted to be independently heated, and an anode within said envelope, an external circuit connected to said electrodes, and a source of electro-motive force applied to said circuit, the degree of vacuity and the electron emission of the cathode being so related to the potential of said source that the flow of current over a range of voltage materially above the ionization voltage is governed by the electric field of the electrons in the vacuous space and the potential applied to said electrodes, operatively independent of gas ionization.

Claim 1. A discharge tube having electrodes at least one of which is adapted to emit electrons, the gas content or residue of said tube and the relation of the parts of

the tube being such that the tube is capable of being so operated in a range below saturation and materially above ionization voltages that the governing or limiting action on the space current due to the electric field of said electrons is substantially unaffected by positive ionization and by secondary electron emission from the walls of the tube.

Claim 2. A discharge tube having a cathode adapted to emit electrons and an anode adapted to receive said emitted electrons, the tube walls being fashioned or shaped to permit direct passage of a useful proportion of said electrons from cathode to anode, the gas content or residue of said tube and the relation of the parts of the tube being such that the tube is capable of being so operated in a range below saturation and materially above ionization voltages that the space current is governed or limited by the electric field of said electrons substantially unaffected by positive ionization.

Claim 3. A discharge tube having electrodes at least one of which is adapted to emit electrons, the gas content or residue of said tube and the relation of the parts of the tube being such that the tube is capable of being so operated in a range below saturation and materially above ionization voltages that in that range the space current is governed by the combined effect of the electric field of said electrons and the potentials applied to said electrodes, the governing or limiting of the current being substantially unaffected by positive ionization and by secondary electron emission from the walls of the tube.

Claim 4. A discharge device comprising a tube and electrodes therein one of which is adapted to emit electrons, the degree of evacuation and the relation of the

parts of the device being such that the device is capable of being so operated, when voltages materially higher than ionization voltages are impressed upon electrodes of the device and when the electron emission has any values such that the space current is below the saturation region at such voltages, that the slope of the line obtained by plotting the logarithms of values of said current as ordinates against the logarithms of the corresponding values of said impressed voltages as abscissae shows no increase for increasing voltage values.

Claim 5. A discharge device comprising a tube and electrodes therein one of which is adapted to emit electrons, the degree of evacuation and the relation of the parts of the device being such that the device is capable of being so operated, when voltages materially higher than ionization voltages are impressed on electrodes of the device and when the electron emission has any value such that the space current is below the saturation region at such voltages, that the line obtained by plotting the logarithms of any values of said current below the saturation region as ordinates against the logarithms of the corresponding values of said impressed voltages as abscissae is straight and continuous.

Claim 6. A discharge tube having electrodes at least one of which is adapted to emit electrons, the gas content or residue of said tube and the relation of the parts of the tube being such that the tube is capable of being so operated, when voltages materially higher than ionization voltages are impressed on electrodes of the tube and when the electron emission has any value such that the space current is below the saturation region at such voltages, that said current varies as the three halves power of said impressed voltages.

Claim 7. A discharge device comprising a tube and electrodes therein one of which is an electron emitting cathode, the degree of evacuation of said device and the relation of the parts of the device being such that the device is capable of being so operated, when voltages materially higher than ionization voltages are impressed on electrodes of the device and when the electron emission is such that the space current is below the saturation region at such voltages, that said current is substantially independent of the cathode temperature and unaffected by secondary electron emission from the walls of the tube.

Claim 8. A discharge tube having electrodes at least one of which is adapted to emit electrons, the gas content or residue of said tube and the relation of the parts of the tube being such that the tube is capable of being so operated in a range below saturation and materially above ionization voltages that the space current is governed or limited by the combined effect of the electric field of said electrons and the potentials applied to said electrodes, substantially unaffected by positive ionization, the heating effect in the tube due to said current occurring substantially only at one or more of said electrodes.

Claim 9. A discharge tube having a cathode adapted to emit electrons, an anode adapted to receive electrons and tube walls fashioned or shaped so as to permit the free passage of a useful proportion of said electrons from cathode to anode, the gas content or residue of said tube and the relation of the parts of the tube being such that the tube is capable of operation with stable and reproducible results substantially unaffected by positive ionization, with currents of at least five milliamperes and with voltages of at least 200 volts.

The character of the invention will appear in the following excerpt from Langmuir's specification:

In order to distinguish electron discharge devices made in accordance with my invention from the prior art, I will explain briefly the character of a pure electron discharge as distinguished from a discharge through ionized gas. In a Geissler tube, and in a Roentgen or Cookes tube the conduction of current is accompanied by and depends upon gas ionization. Without a certain minimum amount of gas an ordinary X-ray tube ceases to operate and as this minimum is approached the resistance of the tube steadily increases.

Scientific research has shown that under certain very carefully controlled conditions with extremely low current values of the order of magnitude of .01 of one milliampere or lower and at low voltages, well below 200 volts, an electrical discharge current may take place in an evacuated space between a heated cathode and a cooperating anode without causing the residual gas to take part in the conduction of current. This effect also takes place in a vacuum when an unheated electrode consisting of certain materials, for example, potassium, is subjected to the influence of light, particularly, to ultraviolet rays. The discharge current is carried by negative charges called electrons, which pass through the vacuous space under the influence of the impressed voltage. In the presence of gas these electrons, when moving with proper velocity, collide with gas molecules and give rise to gas ionization which completely changes the phenomena accompanying the discharge. The gas molecules are split up into electrons and larger and more slowly moving positive ions. * * * As gas ionization continues at higher voltages a blue glow may appear. The

cathode under these conditions is electrically disintegrated, technically is "sputtered," which causes its rapid destruction. The bombardment of the cathode by positive ions also causes heating of the cathode.

* * * * * * * * * *

In devices made in accordance with my invention gas ionization is either entirely absent or is negligible and a discharge takes place which is distinct in its characteristics from the described discharge taking place in an ionized gas.

* * * * * * * * *

The discharge current passing through a given space with the cathode at a sufficiently high temperature so as to give a sufficient electron emission for a given voltage varies directly with the 3/2 power of the impressed voltages, above a minimum voltage depending on the characteristics of each particular device. In other words, the 3/2 power law holds strictly only above a certain minimum voltage for a given device, usually a few volts. If the electron emission is not sufficient, as, for example, when with the cathode at a given temperature the voltage exceeds the value at which all the electrons emitted are utilized, then a further increase in voltage produces substantially no change in current. The discharge is independent of the vacuum, providing the pressure is below the minimum at which gas ionization by collision will take place. As distinguished from discharges in the presence of positive ionization, the pure electron discharge is characterized by regularity and reproducibility with given conditions.

* * * * * * * * * *

As shown in Fig. 4, the various parts of the apparatus may be mounted in a tube, or envelope 1, upon a pedestal

2, similar to the mount used in incandescent lamps. The cathode 3 is centrally located and may consist of a short straight filament not shown in Fig. 1, but indicated by the position of terminals 5, 6, and shown plainly in Fig. 3. The cathode shown in Fig. 2 consists of a V-shaped conductor. Either form may be used, the particular form of cathode being ordinarily determined by convenience of construction. Preferably the cathode conductor is held taut by a spring 7 to avoid contact of the cathode conductor with the grid by sagging when the metal is expanded at a high temperature. The filament 3 is mounted between two oppositely disposed supports 9, 9', in this case constituting a closed loop, which may consist of insulating material, such as glass or quartz, but in some cases may to advantage consist of metal. Upon this framework is wound a discharge-varying conductor 10, ordinarily called a grid. The turns of the wire are closely adjacent to each other and are also very closely adjacent to but are out of contact with the incandescent cathode. By means of this grid 10 potential may be applied to exert a static control upon the movements of the electrons. A negative potential applied on the grid reduces the flow of current from cathode to anode in proportion to the degree of negative charge. A positive grid potential assists and directs the flow of current from cathode to anode in proportion to the degree of its charge.

The supporting framework for the cathode and grid is attached to a rod 11, mounted upon the stem of the tube. Adjacent to the cathode and grid is the anode 12 which in the present case has been indicated as consisting of a wire strung in a zigzag manner over hooks 13 upon fork-shaped supports 14 and 15, but it is not necessary that it should assume this particular form. Both

anode and grid preferably consist of tungsten, but other refractory metals may be used. By constituting the anode a continuous conductor it can be conveniently heated by passage of current during evacuation of the device and for this purpose is attached to leading-in conductors 16 and 17. The grid is indicated in Fig. 1 as being attached to leading-in conductors 18 and 19 at opposite ends, although but one terminal is ordinarily necessary.

* * * * * * *

For the evacuation of the device the glass walls of the tube are carefully heated to as high a temperature as the glass will stand without softening and in general the most approved methods of incandescent lamp exhaust are used. The evacuation of the tube preferably while still heated is carried out by means of a suitable evacuating means, for example, a Gaede molecular pump, which removes vapors as well as gases. Chemical evacuating means such as electrically vaporized calcium or magnesium may also be used. Either before or during the evacuation the anodes may be heated, especially when the anodes are to be run at elevated temperature during the normal operation of the device. In this case the temperature is preferably carried close to brilliant incandescence. In the case of the structure shown in Fig. 1, the heating may take place by passing an electrical current through the wire 12. In fact, the heating may take place in a suitable vacuum furnace, the temperature preferably being raised to 2500° C. or even higher. However, heat alone will not remove all the gas liberated by the electron discharge, but this gas is driven out even at ordinary temperatures by the discharge itself. The discharge appears to affect especially the surface of the metal. Heating is a valuable aid in bringing gases from

the interior of the metal body into the sphere of action of the discharge but may be omitted when the devices are not heated during normal operation.

The determination of the question of patentability presented by the motion to dissolve is not rendered easier by the testimony of the eminent physicists appearing in the record, since the discussion has not been kept within the scope of the order permitting the taking of testimony and additional publications not mentioned in the motions to dissolve, have been injected into the record from time to time. Under the Commissioner's order testimony cannot be taken to add to the disclosures of the references, but with respect thereto is to be limited to showing the character and meaning of the terms used therein and how these disclosures would have been understood by those skilled in the art at that time. Evidence given in the light of publication subsequent to the alleged anticipating references is not helpful for the present purpose, but is confusing and tends to mislead in that it does not bring out clearly the meaning of terms as understood at the dates of issuance of the references upon which reliance is placed but tends to show the meaning of terms as they would be understood more recently by scientists who have a much larger fund of information, theoretical and experimental, upon which to draw.

The consideration required by the motions will therefore be confined to that part of the prior art actually cited in the motions to dissolve and listed on page 1 of the "Reference Book" submitted by the party Arnold. It is apparent after a review of the record that there is no single element which is broadly novel in the assemblage of elements making up an electron discharge device of the character defined in the issue. An exacuated tube

having therein an incandescent electron-emitting cathode and an anode was old prior to the filing of Langmuir's application, and methods of attaining high vacua, sufficient to give a relatively pure electron discharge in a properly designed tube, were also well known and available to persons skilled in the art. It is well settled, however, that the patentability of a combination is independent of the novelty of any of its constituent elements (Leeds *v.* Catlin, C. D. 1909, 549). There remains for determination the question of the patentability of the combination as a whole.

The importance and the far reaching effect of the improvement are attested by its numerous industrial applications, Langmuir's record, page 586. No argument is necessary to establish utility.

We may lay aside those alleged anticipating disclosures, such as Lenard, Gehrts and Dember, which pertain to photo electric devices using small currents of the order of 10-9 amperes or less. No effort was made at the hearing to include these within the scope of the count or the claims retained and they are avoided by evident limitations, for example, space charge does not govern the flow of current in these devices. It is not seen that any of the remaining references made fully available to the public by proper disclosure the device now claimed in the issue as reformed, or that the proposed combinations of references, with results not suggested by any one of them, were obvious. The fact seems incontrovertible that a substantial and valuable contribution to the art has been made and that, within the limits explicitly stated or necessarily implied in the claims retained, it is entitled to patent protection.

The improved mode of operation of prior devices made possible in a later development of the art by more effi-

cient means does not fairly negative patentability of the device of the issue where the public was not fully advised of all the correlated facts necessary to secure the improved mode of operation.

Richardson investigated experimentally and theoretically the law of emission of electrons. As the claims now stand it is a matter of little moment whether the theory of electron emission was new or old when Langmuir entered the field, since no claims cover broadly the Richardson theory and the claims retained are directed to practical forms of the invention which Richardson did not disclose.

The Von Lieben relay has some features in common with the device of the issue, but it cannot be said that it was available for use without experimentation, by persons skilled in the art, in a manner to satisfy present day requirements.

It is not seen that the Majorana publications present anything definitely anticipating any of the claims herein discussed.

The publication by Child is apparently not urged as a sufficient and complete anticipation in itself. Its interest lies in the fact that the 3/2 power law is clearly disclosed therein. Richardson remarks "There is no doubt that this law represents a fair approximation to the experimental facts in simple arrangements of electrodes such as parallel plates and concentric cylinders. The law is thus of considerable practical interest and Child is entitled to the credit, such as it is, of having given the first theoretical demonstration of it."

The Lilienfeld device with its long, constricted tube is obviously impractical for any commercial purpose. The walls would tend to melt under electron bombardment

and would become so hot as to furnish vapors under their own vapor pressure.

The Fleming valve and the DeForest audion apparently depended to some extent upon gas ionization and the inventors did not clearly and fully inform the public how their devices must be designed or treated to get the effective results now demanded in thermionic devices. It was not essential for their purposes that they should understand the theory of operation or use all the precautions later found to be desirable.

The words of Judge Coxe are pertinent at this point:

> "The question is, what does the prior publication say? Not what it might have said or what it should have said. If prior patents and publications can be reconstructed by extrinsic evidence to fit the exigencies of the case, the inquiry will no longer be confined to what the publication communicated to the public, but it will be transferred to an endeavor to ascertain what its author intended to communicate." (Badische Anilin & Soda Fabrik *v.* Kalle, 104 F. R., 802-808.)

As for Thomson, Arnold's own comment may be sufficient:

> "He does not anywhere state that the ionization point depends in a complicated way on the degree of vacuum and the temperature of the filament and nowhere hints that said ionization is highly deleterious to the operation and life of the practical devices utilizing the phenomena of thermionic emission. Finally, he does not anywhere even remotely hint or suggest that the point at which appreciable ionization sets in is precisely the point at which rectification in the two-element device and repeater action in the three-element device becomes imperfect."

The suggestion that the alleged invention represents a mere difference in degree over the prior art loses its force in the presence of the results accomplished (Edison *v.* U. S. Co., 52 F. R., 300, 308; General Electric Co. *v.* Nitro Tungsten Lamp Co., 282 O. G., 195), and the allegation of no invention is overcome by the presumption of invention in the transformation of laboratory experiments, and erratic and unstable devices into reliable, stable, and successful commercial products (Marconi *v.* DeForest, 243 F. R. 560).

The charge of new matter is predicated upon the assertion that many of the criteria set up by Langmuir in his claims are independently disclosed in his original specification and many are not disclosed at all. Some, it is admitted, are capable of being inferred from the original specification and the drawings. These will not be discussed.

In claim 26, the criterion R of Arnold appears which states that the current flow is governed by the electron field or by the same and the electrode potential. This is the "space charge effect" of which there is no direct mention in Langmuir's original specification. However, it is argued by Arnold that the effect had been recognized by many others before Langmuir, including Child, Lenard, Deininger, and Lilienfeld. If it is to be regarded as an effect incidental to a theory of operation known to workers in the art, it is not necessary that mere theory should be set forth in the specification or that an applicant should adhere to the same theory which he originally recited. If on the other hand, it is an essential and novel feature of Langmuir's invention upon which the patentability of certain claims may rest the lack of definite disclosure would support the charge of new matter.

Adopting the first point of view, the space charge effect is held to be not new matter.

Criterion T, that the testing range lies below the voltage at which saturation is obtained is in the nature of a limitation and not an attempt to cover an undisclosed range.

Criterion V, that the discharge is unaffected by secondary electron emission from the tube walls seems to be a necessary result in a properly designed tube, the embodiment in Fig. 1 of the Langmuir drawing being a practical form of tube.

Criterion W, that the current is independent of the cathode temperature appears to be necessarily involved in the operation of the tube when working under the conditions stated in proposed claim 7, and not a function dependent upon something undisclosed.

Criterion X, that the heating effect in the tube shall occur only at an electrode, defines a useful result of the proper design of the tube walls such that the walls of the tube shall not be undesirably heated. There is no substantive new matter in the statement.

The negative limitations in which part of the alleged new matter is included do not appear to demand a specific disclosure in the specification. What is excluded from the scope of the claim by negative limitations, if old, need not be explicitly set forth in the specification, since that which is old is, as it were, written into the specification. (Webster Loom Co. *v.* Higgins, 105 U. S., 580, 586.)

As to the contention that the claims cover merely an effect or result obtained by any means, it is held that the claims define a combination in which one or more of the several elements are qualified by statements of function. The gas content or residue may be accepted as a physical element, the highest attainable vacuum allowing the re-

tention of millions of molecules of gas in a cubic centimeter, and the qualification of the gas content in terms of the result obtained sets forth a material modification of one element of the combination to which fairly definite functions are attributed and thereby avoids the criticism that the claims are for an effect or result obtained by any means.

The difficulty of drafting claims satisfactorily defining the invention and free from objectionable statements of function or result, without introducing unnecessary limitations, is recognized. No better form of claim has been suggested, and it seems unavoidable in the present instance that the device must be defined by what it does, rather that what it appears to be. The situation is similar to that in chemical cases where identity in chemical composition is present, attended by marked difference in results produced.

The motions to dissolve are granted as to counts 1, 2, 3, 4, 6 and 7 and denied as to count 5.

The motions to amend are granted as to claim 26 and claims 1 to 9, inclusive, and denied as to claims 24, 25, 27 and 28.

The withdrawal of counts 1, 2, 3, 4, 6 and 7 and claims 24, 25, 27 and 28 by Langmuir is taken as a waiver of appeal, and no limit of appeal is set.

If the party Arnold desires to contest priority as to claim 26 and claims 1 to 9, inclusive, he should present them by suitable amendment within twenty days.

I. P. DIANEY,
Law Examiner.

February 25, 1921.

Opinion of the Interference Examiner on Priority of Invention.

October 21, 1922.

(Interference Record, p. 2475.)

IN THE UNITED STATES PATENT OFFICE.

Patent Interference No. 40,380.

ARNOLD,

v.

LANGMUIR.

Electric Discharge Apparatus and the Process of Repairing the Same.

Application of Harold DeForest Arnold filed Nov. 2, 1915, Ser. No. 59,210.

Application of Irving Langmuir filed Mar. 14, 1916, Ser. No. 84,242, for renewal of Ser. No. 795,610, filed Oct. 16, 1913.

Messrs. DE WITT C. TANNER and JOHN G. ROBERTS for Arnold.

Messrs. ALBERT G. DAVIS and ALEXANDER D. LUNT for Langmuir.

This interference involves high vacuum tubes. Structurally, the tubes of the issue are similar to the two electrode tube of Fleming and the three electrode tube of DeForest, well known in the art long prior to the dates alleged by either party herein involved. A controversy has arisen as to just what improvement over the prior art is in issue. Arnold, on the one hand, contends it is a

mere improvement in the degree of vacuum of devices in the prior art, while Langmuir contends it is a correlation of the physical structure of the tube with relation to the degree of vacuity, resulting in a new device. As will be hereinafter shown, both parties realized the issue by taking an ordinary DeForest audion structure, and removing the gases therein to a probably greater degree than was usual in the commercial audion. Langmuir's correlation may be obtained by taking any usual vacuum tube of the prior art, denuding the walls and electrodes of gas, and removing the gas in the tube by means well known and understood in the prior art, until a vacuum of higher degree is attained, than was originally present in the tube. In other words, by simply removing the occluded gases and increasing the vacuum of the commercial prior art devices to a certain degree, the issue of this interference is fully realized. The degree of vacuum necessary depends largely on the mechanical structure of the tube chosen, and to this extent the issue defines a correlation.

The history of the counts in issue is unusual and has an important bearing on the construction to be placed thereon. A vigorous attack on the issue, as originally framed, was launched by Arnold. Permission was obtained to take testimony before the law examiner on motion to dissolve in order to explain references and the meaning of terms in the art. A voluminous record was presented by both parties on the issue of patentability, and this record has been stipulated as part of the priority record. As a result of these proceedings, and of motions to amend the issue by Langmuir, the issue was reformed to include the following counts held patentable by the law examiner:

Count 1. A high vacuum electron discharge device comprising an envelope, an incandescent cathode, and

an anode, the space in said envelope being evacuated to such degree that the passage of current produces no appreciable positive ionization when the impressed voltage is as high as 200 volts.

Count 2. An electrical device comprising the combination of a sealed evacuated envelope, a cathode adapted to be independently heated, and an anode within said envelope, an external circuit connected to said electrodes, and a source of electromotive force applied to said circuit, the degree of vacuity and the electron emission of the cathode being so related to the potential of said source that the flow of current over a range of voltage materially above the ionization voltage is governed by the electric field of the electrons in the vacuous space and the potential applied to said electrodes, operatively independent of gas ionization.

Count 3. A discharge tube having electrodes at least one of which is adapted to emit electrons, the gas content or residue of said tube and the relation of the parts of the tube being such that the tube is capable of being so operated in a range below saturation and materially above ionization voltages that the governing or limiting action on the space current due to the electric field of said electrons is substantially unaffected by positive ionization and by secondary electron emission from the walls of the tube.

Count 4. A discharge tube having a cathode adapted to emit electrons and an anode adapted to receive said emitted electrons, the tube walls being fashioned or shaped to permit the direct passage of a useful proportion of said electrons from cathode to anode, the gas content or residue of said tube and the relation of the parts of the

tube being such that the tube is capable of being so operated in a range below saturation and materially above ionization voltages that the space current is governed or limited by the electric field of said electrons substantially unaffected by positive ionization.

Count 5. A discharge tube having electrodes at least one of which is adapted to emit electrons, the gas content or residue of said tube and the relation of the parts of the tube being such that the tube is capable of being so operated in a range below saturation and materially above ionization voltages that in that range the space current is governed by the combined effect of the electric field of said electrons and the potentials applied to said electrodes, the governing or limiting of the current being substantially unaffected by positive ionization and by secondary electron emission from the walls of the tube.

Count 6. A discharge device comprising a tube and electrodes therein one of which is adapted to emit electrons, the degree of evacuation and the relation of the parts of the device being such that the device is capable of being so operated, when voltages materially higher than ionization voltages are impressed upon electrodes of the device and when the electron emission has any value such that the space current is below the saturation region at such voltages, that the slope of the line obtained by plotting the logarithms of values of said current, as ordinates against the logarithms of the corresponding values of said impressed voltages as abscissae shows no increase for increasing voltage values.

Count 7. A discharge device comprising a tube and electrodes therein one of which is adapted to emit electrons, the degree of evacuation and the relation of the

parts of the device being such that the device is capable of being so operated, when voltages materially higher than ionization voltages are impressed on electrodes of the device and when the electron emission has any value such that the space current is below the saturation region at such voltages, that the line obtained by plotting the logarithms of any values of said current below the saturation region as ordinates against the logarithms of the corresponding values of said impressed voltages as abscissae is straight and continuous.

Count 8. A discharge tube having electrodes at least one of which is adapted to emit electrons, the gas content or residue of said tube and the relation of the parts of the tube being such that the tube is capable of being so operated, when voltages materially higher than ionization voltages are impressed on electrodes of the tube and when the electron emission has any value such that the space current is below the saturation region at such voltages, that said current varies as the three halves power of said impressed voltages.

Count 9. A discharge device comprising a tube and electrodes therein one of which is an electron emitting cathode, the degree of evacuation of said device and the relation of the parts of the device being such that the device is capable of being so operated, when voltages materially higher than ionization voltages are impressed on electrodes of the device and when the electron emission is such that the space current is below the saturation region at such voltages, that said current is substantially independent of the cathode temperature and unaffected by secondary electron emission from the walls of the tube.

Count 10. A discharge tube having electrodes at least one of which is adapted to emit electrons, the gase content

or residue of said tube and the relation of the parts of the tube being such that the tube is capable of being so operated in a range below saturation and materially above ionization voltages that the space current is governed or limited by the combined effect of the electric field of said electrons and the potentials applied to said electrodes, substantially unaffected by positive ionization, the heating effect in the tube due to said current occurring substantially only at one or more of said electrodes.

Count 11. A discharge tube having a cathode adapted to emit electrons, an anode adapted to receive electrons and tube walls fashioned or shaped so as to permit the free passage of a useful proportion of said electrons from cathode to anode, the gas content or residue of said tube and the relation of the parts of the tube being such that the tube is capable of operation with stable and reproducible results substantially unaffected by positive ionization, with currents of at least 5 milliamperes and with voltages of at least 200 volts.

Count 12. Apparatus for controlling an electric current comprising a vacuum tube, an anode and an electron emitting cathode in the circuit of said current and within said tube, the degree of evacuation of the tube and the relation of its parts being such that for voltages materially above ionization voltage the current is governed or limited by the electric field of the electrons in said tube substantially unaffected by positive ionization, and a third electrode in said tube by which an auxiliary controlling electromotive force may be superposed to modify the effect of said electric field and control said current in a stable and reproducible manner.

Count 13. The method of controlling an electric current in one circuit by an electromotive force in another

circuit which consists in causing said current at voltages materially above ionization voltages to pass as a discharge across a vacuous space between an electron emitting cathode and an anode, maintaining a high vacuum in said space, governing or limiting the current by a space charge effect in said space substantially unaffected by positive ionization, and superimposing the effect of said electromotive force on said space charge effect to control said current in a stable and reproducible manner.

The peculiar relation of the devices in issue to the prior art and the difficulty recognized by the law examiner of distinguishing therefrom in formulating the counts, becomes important in rendering a decision on priority. The decision of the law examiner with respect to patentability will be followed. This, however, does not avoid the necessity for a close analysis of the issue in the light of the record in considering the question of priority. Both Langmuir and Arnold have produced devices which, as previously pointed out, in mechanical structure, have their apparent counterparts in the prior art. Eminent physicists called on behalf of Arnold have expressed opinion that what was accomplished did not amount to invention. The case is of far reaching importance, and in its present form, the issue apparently dominates the entire commercial field of thermionic vacuum tubes. In order to arrive at a conclusion with respect to priority an effort must, therefore, first be made to determine the proper limits of the counts in view of the prior art.

Controversy has arisen concerning proper tests affording a means for distinguishing an improved device from the usual prior art device. The determination of a satisfactory means of recognition is essential. Preliminary inquiry must also be made to ascertain the nature of the

improvement in issue, and a criterion must be established affording a standard for comparison.

Taking up first the problem of construing the counts in the light of the prior art, the finding of the law examiner on motion to dissolve is clearly and concisely set forth in the following quotations:

> "* * * It is apparent after a review of the record that there is no single element which is broadly novel in the assemblage of elements making up an electron discharge device of the character defined in the issue. An evacuated tube having therein an incandescent electron emitting cathode and an anode was old prior to the filing of Langmuir's application, and methods of attaining high vacua, sufficient to give a relatively pure discharge in a properly designed tube, were also well known and available to persons skilled in the art. * * * and the allegation of no invention is overcome by the presumption of invention in the transformation of laboratory experiments, and erratic and unstable devices into reliable, stable and commercial products."

This view of the state of the art is in apparent accord with the entire record. The principal prior art devices to be here considered are those of Lilienfeld, Fleming and DeForest. For convenience, the reference book presented by Arnold on motion will be considered as disclosing correctly the pertinent portions of the publications therein referred to, since no attack on the authenticity of any extract has been made.

The Lilienfeld device was disclosed fully in printed publications of 1910 and 1911 (R. B. pp. 130 to 166) and consisted of two bulbs, one containing a Wehnelt heated cathode, the other containing a cold anode both connected

by a relatively long narrow tube. In the narrow tube were located sounding electrodes to measure potential gradient, the whole being connected to an evacuating system with arrangements to temporarily seal the device off from the pumping system (R. B. pp. 141 to 147; Langmuir p. 353, Q32, section 3, and p. 835, XQ205, L. M. R.). This plainly was a device for experimental purposes only, but was useful for laboratory investigation of laws and theories. Arnold's witness Richardson, referring to Lilienfeld's experiments says (p. 92 R. D.):

> "In Annelen der Physick, Volume 32, page 673, (1910) Lilienfeld investigated the characteristics for a tube with a Wehnelt cathode under condition of vacuum such that further evacuation made no difference to the characteristics * * *."

Speaking of the results attained by Lilienfeld, Richardson attributes to him the experimental determination of the three-halves power law, urged by Langmuir as the principle test for the presence of the issue, in the following words (p. 94, R. D.):

> "Lilienfeld thus arrived at the 3/2 power law as a purely experimental result and he had no theoretical calculations to guide him."

On page 104 R. D., he refers to a "pure electron discharge device such as Lilienfeld's." Respecting the work of Lilienfeld's, Langmuir testifies:

> "(19) Lilienfeld proved beyond question, I think, that he obtained discharges, in some cases at least, in which the effects that he measured were not dependent upon gas ionization * * *." (P. 366, Q32, section 19, L. M. R.)

On page 370, L. M. R.:

> "(24) The heating of the walls of the tube and the fluorescence of the gas furnish absolute proof that the walls are being bombarded by electrons, since Lilienfeld's experiments are made under such conditions that positive and negative ions could not have been present in sufficient numbers to bring about this result."

On page 377, L. M. R.:

> "It should be noted that the 3/2 power law held in Lilienfeld's tube only over a very narrow range of voltage."

On page 507, L. M. R.:

> "(25) Lilienfeld probably succeeded in obtaining a discharge in high vacuum substantially free from effects of positive ionization in the device he described in his 1910 paper (see p. 364 et seq.).

The voltages Lilienfeld used were as high as 6,000 volts (L. M. R. p. 353) and he had generators capable of delivering 10,000 volts (L. M. R. p. 359). According to the replotted diagrams of his results which have not been challenged (R. B. pp. 149 and 150), at 350 volts between the sounding electrodes, approximately 10 milliamperes of current flowed. The Lilienfeld disclosure may, therefore, safely be characterized as a two-electrode high vacuum tube in which the effects of positive ionization are not appreciable with currents of at least five milliamperes at potentials considerably above two hundred volts, but useful only for performance of laboratory experiments. All parties are agreed that ionization potential for gases commonly found in thermionic devices lies between 10 and 20

volts (Langmuir, Q26, Sec. 13, p. 216, L. M. R.; Arnold, p. 15, A. P. R. and Langmuir Brief p. 32). Therefore, Lilienfeld produced and disclosed a high vacuum electron discharge tube unaffected by appreciable ionization at voltages materially above ionizing potentials. Even though this device would be impractical for present day thermionic purposes, and was in fact never intended for use in such a relation, nevertheless, the counts of the issue must be distinguished therefrom, otherwise the terms will be squarely met by a prior art disclosure. Unless distinguished, the counts will not set forth the contribution to the sum of human knowledge (General Electric Co. *v.* Nitro Tungsten Lamp Co., 282 O. G., 195; 266 Fed. Rep. 994) and will not point out the improvement in the manner required by Sec. 4888, R. S.

The Fleming disclosures bear on the production of a two-electrode vacuum tube, which has been used commercially to some extent. The structure of this tube is disclosed in a paper published by Fleming in the Proc. Royal Soc. Vol. 74, pp. 476-487, January 24, 1905, in U. S. Patent No. 803,684 to Fleming, and in a paper published in the Scientific American Supplement No. 1568, pp. 25129-25131, January 20, 1906, pertinent extracts of which are reprinted in Arnold's Reference Book, pp. 47 to 71. The degree of vacuum specified by Fleming in his disclosures is the only element which need be considered, since the remaining elements are unquestionably disclosed. His tube consists of an ordinary incandescent lamp bulb into which has been sealed in the usual way, a plurality of electrodes in the form of filaments, or of a plate and a filament (R. B. pp. 49, 55, 60 and 68). Regarding the degree of vacuum Fleming states in his patent No. 803,684 (R. B. pp. 56 and 57):

"As a very high degree of vacuum should be obtained in the bulb *a*, and as a considerable quantity of air is occluded in the conductors, these should be heated when the bulb is being exhausted. The filament *b* can be conveniently heated by passing a current through it, while the cylinder *c* can be heated by surrounding the bulb *a* with a resistance-coil through which current is passed, the whole being inclosed in a box lined with asbestos or the like."

In the Royal Soc. paper (R. B. p. 49) referring to the degree of evacuation he states:

"The bulb must be highly exhausted to about the pressure usual in the case of carbon filament incandescent lamps, and the metal cylinder or plate must be freed from occluded air."

In his Scientific supplement article the following appears:

"Let this bulb be exhausted as completely as possible so that in it the highest attainable vacuum is made. To achieve this, the filaments must be heated to bright incandescence while exhaustion is going on." (R. B. p. 60)

and on page 65, R. B.

"If the pressure is great enough electrons may be projected from the negative electrode. If, however, the electrode is surrounded by air molecules at normal pressure, the electrons projected from the metal never attain a very high velocity."

He then goes on to define a high vacuum as "one-hundred millionth of an atmosphere" and defines what he means by "hot" and "cold" and "high" and "low" voltages. It is very clear that Fleming attributes the action of his valve, as early as 1906, entirely to electron flow, and con-

tended that the presence of gas was undesirable, due to the interference with velocity of electrons thereby occasioned. Langmuir himself says (Langmuir, p. 14; L. P. R.):

> "Fleming's idea in wishing to use a high vacuum was undoubtedly based upon a vague desire to avoid ionizing effects."

The definite measure of Fleming's vacuum, which he considered the "highest obtainable," is given as that of a carbon filament lamp of that period. Long prior to the date of the Royal Soc. paper in 1905, it was customary to heat the bulbs and filaments highly during exhaust to remove occluded gases. Iodine, sulphur, and powdered silver were used to remove mercury and remaining gases (Duncan, pp. 71-72, R. B., May, 1896, De Land, pp. 73-74, R. B., June, 1897, Anonymous, pp. 74-75, R. B., May, 1902; Del Mar, pp. 75-76, R. B., May, 1902; and Doane, pp. 76-77, R. B.). Chemical methods of getting high vacua were also in use (Doane, p. 78-79, R. B., May, 1904). In the Scientific American supplement article, Fleming refers to Sir James Dewar's method of obtaining a high vacuum (Fleming, pp. 59-60, R. B.; Dewar, pp. 3-7, R. B.).

Van der Bijl, testifying in rebuttal for Arnold, made bulbs following Fleming's disclosure, which he exhausted without taking the precaution of heating the bulbs. The filaments were simply glowed during exhaustion. He also made tubes in this manner using tungsten filaments. The results of these experiments are given on pages 104 to 130 of Arnold's rebuttal testimony on motion (Van der Bijl, Q8, A. M. R.). The characteristics obtained indicate clearly that a pure electron discharge was obtained at voltages high above the ionization potential. Respecting the

precautions taken to obtain a high vacuum, Van der Bijl says (p. 128):

> "In doing so I did not take precautions that a man skilled in the art would have done prior to 1913. In the manufacture of lamps, for example, precautions are taken and have been taken for many years, that are superior to those I took in evacuating these bulbs, and yet these bulbs give pure electron discharge characteristics up to several hundred volts and several milliamperes space current."

and on page 171, A. M. R.:

> "As I have stated before, these tubes were evacuated simply by glowing the filaments to bright incandescence and not baking the bulbs. I used a standard pumping system which is superior to the pumps in use around 1906. In those days the Toepler pump was the one used by some scientists. The Toepler pump is slower, so that my advantage lay in the time of pumping."

Van der Bijl was fully cross-examined regarding these experiments, the manner of making the tubes and the apparatus used in exhausting them. The law examiner on motion held that the Fleming tube was dependent to some extent on gas ionization and the disclosures were not sufficiently clear and full to inform the public how to get the effective results now demanded in thermionic devices. Van der Bijl's experiments and his testimony have not been discussed by the law examiner. It must be assumed, for the purposes of the determination of priority, that these experiments were inconclusive.

A tube made according to Fleming's disclosures, adopting all the precautions in obtaining the usual vacuum in incandescent light bulbs of the prior art, cannot be within

the issue. A review of the precautions common in denuding filaments and bulbs of gas during pumping and in removing residual mercury vapors, indicates the extreme precautions necessary to produce a device embodying the issue. Considering the situation, it becomes apparent that the means adopted to procure a vacuum furnishes no reliable guide in determining whether a device corresponding to the issue has been produced.

The remaining important device limiting the field of the counts, is the DeForest audion. DeForest attributed the action of his audion to residual gas and, therefore, the disclosure of his patents may be disregarded. The inquiry must be directed to the characteristics of the device actually in commercial use prior to the work of Langmuir and Arnold. The DeForest audions actually in use in the prior art clearly must limit the scope of the issue. Regarding the DeForest audion, Langmuir testified (L. P. R. p. 39):

> "We should keep in mind, however, that all DeForest audions from 5 to 20 or 30 volts operated substantially unaffected by positive ionization, so that this demonstration could have been made with any audion."

Referring to audions used in tests for telephone repeater service by Kendall, where voltages from 30 to 50 were used in actual practice while considerably higher voltage (about 75 volts corresponding to 52 cells) Langmuir says (L. P. R., pp. 55 and 56):

> "These power outputs do not appear to be appreciably better than might have been expected from many original DeForest audions. Results of this kind could have been obtained by devising methods for making audions of uniform quality, but with no radical improvement in quality."

Arnold exhibit 25 referred to by Langmuir for this data shows, however, that satisfactory telephone conversation was carried on with New York and these tests were immediately prior to installation of commercial service which lasted daily for six months (Kendall, A. P. R. pp. 104 and 105). The test of service as a telephone repeater appears to establish beyond question that the devices were stable and, therefore, substantially unaffected by positive ionization up to at least 41 volts and probably higher. Certainly erratic behavior could not be tolerated under such conditions.

Arnold's testimony with respect to the DeForest audion is substantially in accord with that of Langmuir as follows:

> "* * * since the voltage in those original tubes ran about 40 volts and the current about 150 microamperes * * *." (Arnold p. 12, A. P. R.)

and on p. 15, A. P. R.,

> "* * * the operating range for the new devices should not only exceed the ionization voltage of 10-20 volts, but should indeed exceed the 40 volts at which the DeForest audion operated."

Referring to audion No. 7, before the vacuum had been improved by burning out one filament, Arnold said (p. 23, A. P. R.):

> "* * * the experiment shows that no ionization was produced, the evidence being that no current flowed between plate and grid up to 48 volts."

In view of this testimony it is clear that the DeForest operated as high as 30 volts without appreciable positive ionization and by simply standardizing production ac-

cording to Langmuir, and without radical improvement in quality, the voltage could be raised as high as 41 to over 50 volts. The counts must, therefore, be limited to devices operating at voltage about 40 or 50 without appreciable ionization.

In deciding the matter of priority it, therefore, becomes evident that the counts must be limited in view of Lilienfeld to a permanently sealed off device more useful than from the standpoint of laboratory experiment or scientific investigation of laws of nature. In view of Fleming and the work of Van der Bijl it is clear that something more than the precautions advocated by Fleming in evacuation is required. If the Fleming disclosures be regarded as insufficient as an anticipation, certainly the suggestion of desirability of a high vacuum in the usual prior art tubes did not require invention. The limits of the De-Forest tube are clear. If the majority of counts are to be held not anticipated by this device, then 30 to 50 volts cannot be construed to be materially above the ionization potential of 10 to 20 volts.

Before the matter of priority is discussed, a satisfactory criterion for recognition of a device embodying the issue must be determined. In general, the improvement consists in making the commercial tubes of the prior art stable and operable in a dependable and reproducible manner at materially higher potentials than was before possible for satisfactory operation. The result has been a marked increase in the power of the tubes and in their general usefulness. This result has been accomplished by removing the gases in the tubes to such an extent that the neutralizing effect of positively ionized gases does not materially affect the negative space charge which is due to the mutual repulsion of electrons. The current is then definitely

limited in a reproducible manner by the space charge effect, electron emission of the filament, applied potential, and the mechanical structure of the tube, and the tube is reliable at potentials considerably higher than before attainable. Langmuir proposes as a test, a three-halves power law which the volt-ampere characteristic of a tube embodying the issue must follow below the saturation region. Langmuir's own testimony, however, shows the variation from this law, which at best is an approximation (Richardson, Qs8 to 11, R. D.), may be so great that the exponent becomes five-halves, and still the device may embody the issue (Langmuir, XQ134, p. 791, L. M. R.). Even in devices considered by Langmuir as following the 3/2 power law, the deviation is apparent from the diagrams given (pp. 145 to 185, L. M. R.), and Van der Bijl's reply to Q10 (A. M. R., pp. 131, 148). Arnold's criticisms of Langmuir's application of the 3/2 power law (pp. 143-146, Q. P. R.) and Richardson's replies to Qs8 to 13 (R. D. pp. 42 to 77) show that the law is approximately true only for a theoretic device of simple construction, and is seldom realized in practice. As a test in this inquiry it will, therefore, be entirely disregarded except insofar as it is necessarily embodied in the terms of counts 6, 7 and 8.

The appearance of blue glow is a more tangible test for the presence of a serious degree of ionization. When blue glow appears, ionization has gone to the extent of destroying the usefulness of the tube for the potential where the glow appears. Van der Bijl, (p. 142, A. M. R.) referring to the VT-1 tube which is commonly used as a radio detector says:

> "but it was found that these tubes were unsatisfactory at 100 volts because they blue hazed although they were perfectly satisfactory at 45 volts."

This tube was widely in commercial use during the war. Arnold in his testimony continually refers to the presence or absence of blue haze as a test for ionization (A. P. R. pp. 5 to 62). Jewett testifies that he recognized blue haze was due to ionization (p. 64, A. P. R.) and this was also recognized by Colpitts (p. 71, A. P. R.). Langmuir's witness Dushman plainly relied on blue haze as a test for serious ionization and lack of reproducibility (pp. 141 to 147, L. P. R.). White relied on blue glow (White, Q28, p. 606, L. M. R.). Even counsel for Langmuir was constrained to admit at the oral hearing that it is a test in the following words:

> "It is quite true that if the vacuum is particularly bad ionization may become so violent as to cause blue glow in the tube. It is a good rough preliminary test. It is probably used a good deal in a rough preliminary way in actual manufacturing practices. And you find where Dushman talks about the glow and of what it is he couples it with reproducibility, and reproducibility is of the essence of the invention."

Blue glow or haze, standing alone would unquestionably be too uncertain as a test for presence of the invention. Relatively, however, a rough test may become satisfactorily accurate by comparison. The record shows that the ordinary DeForest audion of the prior art blue hazed at around 40 or 50 volts (Langmuir, p. 71, L. P. R.; White, XQ109, p. 643, L. M. R.; Arnold, p. 12, A. P. R.). Arnold considers a tube which does not blue haze at 68 volts a high vacuum tube. As previously pointed out, Langmuir considers the tubes used by Kendall as telephone repeaters in November, 1913, to be no radical improvement over the DeForest audion. Since these tubes operated

at 41 to 50 volts without appreciable ionization, in view of Van der Bijl's testimony relating to the VT-1 tube (p. 142, A. M. R. above quoted), it is probable that blue glow would have appeared below 100 volts. Measuring by Langmuir's standard, a tube which does not show blue glow at voltages about 100 should embody a radical improvement over the DeForest tube of the prior art. Lack of blue glow at potentials above 100 volts will, therefore, be accepted as a test for a tube in which positive ionization is not appreciable at voltages materially above ionization voltages, within the meaning of these terms in the issue. For the purposes of this case it becomes unnecessary to decide whether a tube which shows blue glow below 100 volts embodies the issue.

Having a tangible guide in mind for determination of when the issue is present, an effort must be made to arrive at a conclusion with respect to the nature of the improvement. That an improvement of wide commercial importance has been effected cannot be denied. The presence of blue glow has long been ascribed to be an effect of gas ionization and the effects of ionization had been studied in the prior art. To suggest, therefore, that the effects of gas ionization could be obviated by removing the residual gas was obvious and too absurdly simple, in view of prior knowledge, to arise to the dignity of invention. The result effected was the elimination of erratic behavior in the prior art devices and making them stable and of reproducible characteristics at potentials theretofore unattainable. Thermionic electron emission had been known and studied for years. Therefore, if a skilled worker in the art of thermionic emission, for example Arnold, could have predicted with certainty, that the erratic behavior of the DeForest audion would disappear

and a reproducible result obtained at higher voltages than previously attainable, by simply evacuating to a higher degree, then there can be no patentability in this issue over the prior art. So far as this tribunal is concerned the law examiner's decision has settled the matter. Since the existence of patentability has been determined, it must be held that for a person with a knowledge of the prior art to foresee and predict the results of removing the residual gas with certainty, would not have been possible. Any forecast must have been a mere hazard which had to be confirmed by actual test before even conception can be said to have been completed. The improvement must, therefore, be classed as a discovery to be patentable, and of the class concerning which Robinson said:

> "In many inventions the act of conception is clearly distinct, in point of time, from that of reduction; and in these cases the rules given above are easily applied. In many others the work of conception and reduction goes forward almost simultaneously, so nearly so that no date can be fixed as that before which the conception was complete and after which the reduction to practice was begun. This is true in nearly all inventions which are the result of experiment,—where the inventor instead of evolving the entire art or instrument out of his own thought, conjectures that such an act or substance will subserve a given purpose, and having tried it accomplishes the end. The production of a new means by this method is equally with the former, an inventive act, but at no instant before the experiment succeeds can it be said that the conception of the invention exists in the inventor's mind. Until that instant it is mere speculation, at most a probable deduction from facts already known and the same act which reduces it to practice gives to conception its definite and final form. Hence the

> date of conception in such cases is the date, not when the experiments begin, but when they end; and the first to bring the art or instrument into successful operation is the first conceiver of the entire invention." (Robinson, Vol. 1, Sec. 381.)

Adopting this view, conception and reduction to practice must be simultaneous in the present case and the first to reduce to practice must, therefore, prevail.

Arnold's earliest work relied upon was with DeForest audions. Seeing one in operation on November 1, 1912, he immediately suggested to Colpitts that thorough removal of the gas would make it steady and reproducible in operation, as well as enabling higher voltages to be used and higher power obtained (Arnold, p. 13; Colpitts, p. 72, A. P. R.). This disclosure was also made to Jewett who testified as follows (p. 65, A. P. R.):

> "Dr. Arnold said that he could make a tube like these DeForest audions but with greater electron emission and so much better evacuated than erratic behavior due to positive ionization would be eliminated, and the device could be operated at the higher voltages necessary for telephone repeater service without sacrafice of its favorable operational features."

This disclosure of Arnold's, although full and complete, must be treated as a speculation which later was verified by actual experiment. Conception can not be awarded thereon. After this conversation, Pierce was assigned to the task of ascertaining the alternating current characteristics of the audion until November 16, 1912, when upon Arnold's orders, Pierce set to work determining the direct current characteristics. (Arnold, pp. 20-21; Pierce, pp. 83-84, A. P. R.) Thereafter tests were carried on by Pierce

on audion No. 7 until one of the filaments burned out on November 29, 1912 (Pierce, p. 85, A. P. R.). The vaporization of the filament which burned out improved the vacuum in audion No. 7. After the burnout it was labeled No. 7A. This method of obtaining a high vacuum is well recognized today as a clean-up process. Absorption of gases by passing a discharge through a tube was well known to the prior art (Thomson's Conduction of Electricity Through gases, 1906 issue, p. 552). The clean-up effect was well recognized in the carbon lamp art prior to the work of Arnold or Langmuir (Proc. A. T. E. E. Vol. 31, pp. 921, 922, 929, 930, read in June, 1912). It is now urged for Arnold that the clean-up of audion No. 7 was deliberate and for the purpose of improving the vacuum. The tests between November 16 and November 29, however, bear the appearance of tests simply made to obtain the characteristics. Arnold nowhere says that he understood the clean-up effect in 1912, or that Pierce was instructed to improve the vacuum in this manner. It is true that he refers to "bombardment" of the grid and plate and also says (p. 22, A. P. R.),

> "By virtue of the clean-up process which sometimes serves to improve the vacuum, and which was a familiar phenomenon in connection with the exhaustion of incandescent lamp * * * I will explain * * * how we proceeded with audion No. 7 to clean it up * * *."

but this is far from a direct statement that what he did then was done for the purpose of cleaning up the audion. Pierce also refers to the experiments as "bombardment" and says (p. 84, A. P. R.),

> "Having cleaned up both the grid and the plate in the manner already described, some more d. c. tests were made."

He does not say that he was instructed to clean-up the tube or improve the vacuum. Although it was some months before an improved vacuum pump arrived, no further effort to repeat this method of improving the vacuum of other tubes was made. In spite of the anxiety to obtain a high vacuum (Arnold, pp. 34-36, A. P. R.) this simple process was never again resorted to although Trimble was set to work during January of 1913 in an effort to duplicate ordinary DeForest audions (Arnold, pp. 36-37, Trimble, 92-93, A. P. R.). In view of the failure to make direct statements regarding knowledge of the clean-up effect, and subsequent conduct in failing to again resort to such a procedure in the months that followed, it must be held that Arnold did not then appreciate what had occurred. The improvement in audion No. 7A occasioned by the filament evaporation was plainly incidental to other tests and unappreciated. It therefore, becomes unnecessary to determine whether audion No. 7A had become sufficiently improved to embody the issue, since even if it had, Arnold could derive no benefit therefrom.

The work from the end of November until April 25, 1913, so far as Arnold is concerned, was directed to the production of tubes which were similar to the DeForest audion and, therefore, did not embody the improvement (Arnold, pp. 34-49). No claim is made during this interval to actual production of an improved tube. On April 25, 1913, audion 20.2 was evacuated using a new Gaede molecular pump, and tested up to 243 volts at which it "stood up" (Arnold, p. 49, A. P. R.) without the appearance of blue haze (Pierce, p. 88, A. P. R.). On May 12, 1913, audions A-3 and B-3 were evacuated together and in a test showed no blue haze at 240 volts (Arnold, p. 49; Pierce, p. 88, A. P. R.). Langmuir has plotted the charac-

teristics for audions A-3 and B-3 (p. 90, A. P. R.). This data was not attacked by Arnold on rebuttal and is apparently accurate. Audion A-3 clearly had reproducible characteristics up to about 70 volts while B-3 was reproducible up to 50 volts since the rising and falling values correspond below these voltages. Lack of blue haze at 240 volts may, therefore, be relied upon to indicate lack of appreciable ionization at 50 to 70 volts but no higher. Audion 20.2 was, therefore, clearly a reduction to practice of counts 2 to 5 inclusive, 9, 10, 12 and 13, since with the ordinary audion structure secondary electron emission from the walls of the tube is not present in appreciable quantities.

It is, however, apparent that none of Arnold's tubes under consideration operated at 200 volts in a reproducible manner, therefore, counts 1 and 11 were not embodied in these tubes. The characteristics plainly do not follow a theoretic 3/2 power law, nor are the logarithmic plots of the characteristics straight line for any material portion of the curve below saturation. Counts 6, 7 and 8 were, therefore, not reduced to practice by Arnold at this time. No further record of the manufacture of audions better in quality than A-3 appear so far as Arnold is concerned prior to Langmuir's filing date. None capable of operating at 200 volts without appreciable ionization, and none with the peculiar characteristics for the entire range below saturation, demanded by counts 6, 7 and 8, were produced. Arnold is entitled to a date of April 25, 1913, for conception and reduction to practice of counts 2 to 5 inclusive, 9, 10, 12 and 13, but has failed to establish conception of the remaining counts prior to Langmuir's filing date.

Considering Langmuir's case, the investigation in 1912 of clean-up effect in nitrogen lamps with two filaments is

the earliest work relied upon. Regarding this work in August of 1912 (Langmuir, pp. 548-550, L. M. R.) Langmuir himself says (p. 546, L. M. R.),

> "by comparison with experiments subsequently made (November and December, 1912) I can now recognize clearly that with this new type of discharge we actually had a device in which the current was limited by space charge substantially independently of positive ionization, at voltages as high as 250 volts."

and on page 55:

> "at that particular time (August, 1912) I did not have any clear understanding of the laws underlying this new type of discharge and I did not know whether, if the vacuum had been still further improved, the currents would not have decreased still further at the lowest possible pressure. In August and September, 1912, however, I was much interested in the subject of thermionic currents in high vacuum, and planned to undertake experiments in order to make a further study of this phenomenon."

According to this testimony, Langmuir did not at that time have any conception of the nature of the device produced and did not realize its value. He was simply interested in phenomena, and planned further study. In September or October, he sought an explanation from Richardson but received none that was satisfactory (Langmuir, pp. 555-556, L. M. R.). A visit by Richardson to the laboratory at Schenectady was arranged. Langmuir testifies with respect to work that followed (pp. 557-558, L. M. R.):

> "(5) After returning to Schenectady I made up my mind that before Richardson visited us I would make a thorough investigation of thermionic cu

rents between two filaments in a very high vacuum, in order to get an understanding of the fundamental laws involved and thus settle once and for all whether or not sure electron currents could be obtained in a practically perfect vacuum."

Referring to work of November 19 and November 20, 1912, Langmuir says:

"The current at these higher temperatures we now know was limited by space charge."

These experiments were admittedly for the sole purpose of scientific investigation of the fundamental law, and Langmuir clearly admits that they were not then understood. At this stage conception of the issue was still manifestly incomplete and certainly no reduction to practice occurred. Langmuir asserts that the Coolidge X-Ray tube was based on his work (p. 574, L. M. R.) and it is urged for him that disclosure to Coolidge was made on December 10, 1912, based on a conversation recorded on pages 156-158 of Langmuir's note book No. 413 (L. Ex. 81). On page 158 in reference to this conversation Langmuir wrote:

"I also pointed out that the current from a hot cathode is much decreased by the presence of gas."

This, however, is contrary to the now well established knowledge of the general increase in current caused by the presence of gas in sufficient quantities to result in appreciable positive ionization. On January 31, 1913, experiments were still being made on the Edison Effect and Langmuir wrote (p. 206, L. Ex. 81):

"This fact is strong evidence against Richardson's theory and indicates importance of anode."

"Richardson's theory" apparently was the "Richardson's law" referred to on page 144 (Ex. 81) which was Richardson's law of emission for hot filaments. On February 14, 1913 (p. 236, Ex. 81), the following note by Langmuir appears:

> "The whole field of pure negative electron discharge is a very important one. I think this work in the laboratory at least was started by me last November and that I had very clear ideas on it on November 22, 1912, see p. 144, a couple of weeks before Coolidge made up his first hot cathode tube."

His ideas of the effects of gas on November 22 are given on page 145 (Ex. 81) as follows:

> "but if gas is there the molecules collide with electrons (which have same velocities as those in filament) and slow them up and make them more readily absorbed by anode wires."

On February 14, 1913, Langmuir did not attribute the gas effect to ionization, but apparently, to slowing up of the electrons by collision. These entries do not show disclosure to Coolidge, and even if they showed complete understanding and disclosure, failure to call Coolidge who was available as a witness, must rob them of any value. Langmuir does not testify that he disclosed to Coolidge and he can derive no benefit from the work done by Coolidge. The entries simply show that the work of Coolidge brought to Langmuir a realization of the importance of the development. They do not show that he realized that tubes embodying any counts of the present issue had been produced.

In February, 1913, Langmuir disclosed to White

> "the two general laws which govern the flow of electron current between an anode and a hot cathode in a high vacuum tube." (White, Q7, p. 596, L. M. R.)

Clearly this is not a disclosure of the issue, for the tube then used, was according to White, simply an experimental device to illustrate general laws.

In March, 1913, a three electrode tube according to Langmuir's direction was made by White. This tube was tested and operated above 100 volts without blue glow (White, Qs16 to 18, pp. 601-603, L. M. R.) and has been offered in evidence as Tungsten Wire Audion No. 2 (L. M. R., Ex. 25). The characteristics were obtained about March 18, 1913, and it was rigged up as a wireless detector about March 19, 1913 (Langmuir, p. 124, L. M. R.). This audion was turned over to Dushman for experiment. April 8, 1913, and of these experiments Dushman says (pp. 143-144, L. M. R.):

> "Finally I did succeed in getting satisfactory results. On these experiments I used voltages up to 240 on the plate of the audion and obtained perfectly reproducible results. There was no evidence of blue glow or any erratic behavior which would indicate positive ionization in the bulb."

Langmuir made an entry on April 15, 1913, in his note book No. 458 (p. 60) that for several hours Dushman found "beautiful proportionality" but that later the conditions could not be produced. The contemporary records for audion No. 2 were available but not produced (White XQ137, p. 654, L. M. R.) and objection was made that the oral testimony is not the best evidence. The best evidence rule applies only to proof of the contents of written instruments, when the contents are in issue. Here the matter in question is the performance of the audion, not the contents of contemporary records. The oral testimony is, therefore, primary, competent, and admissable. Failure to produce the records which are secondary evi-

dence simply goes to the weight of the oral testimony. The evidence establishes beyond reasonable question that prior to April 15, 1913, Langmuir had produced a three electrode tube which did not show blue glow at voltages above 100. On this date Langmuir had, therefore, conceived and reduced to practice counts 2 to 5 inclusive, 9, 10, 12 and 13.

On July 9, 1913, Dushman sealed off a high power tube which stood 400 watts without blue glow and stood 20,000 volts with 110 milliamperes current flowing (pp. 264, 265, L. Ex. Q; Dushman, p. 146, L. M. R.). Langmuir referred to this as the first successful hot cathode relay (L. Ex. *U.* p. 222). This tube clearly embodied counts 1 and 11 of the issue and Langmuir is entitled to July 9, 1913, as a date of conception and reduction to practice of these counts.

No evidence of the production of any tube, by Langmuir, whose characteristic follows the 3/2 power law or has a straight line characteristic on a logarithmic plot for the entire range below saturation has been adduced prior to Langmuir's filing date. Since it has been held that his application supports such counts as 6, 7 and 8 Langmuir is restricted to his filing date for their conception and reduction to practice.

Being the first to conceive and reduce to practice with respect to all the counts in issue, Langmuir is entitled to prevail.

Priority of invention is hereby awarded to Irving Langmuir, the senior party.

Limit of appeal: November 10, 1922.

W. S. RUCKMAN,
Examiner of Interferences.

October 21, 1922.

Decision of the Examiners-in-Chief.

U. S. Patent Office,
Examiners-in-Chief,
Apr. 21, 1923.

Appeal No. 8640, Paper No. 213.

Decision.

Hearing: February 16, 1923.

Appeal No. 8640.

U. S. Patent Office, April 21, 1923.

Before the Examiners-in-Chief, on Appeal:

In the matter of the interference between the application of Harold de Forest Arnold, filed November 2, 1915, Serial No. 59,210, and the application of Irving Langmuir, filed March 14, 1916, Serial No. 84,242, for renewal of an application, Serial No. 795,610, filed October 16, 1913. Interference No. 40,380.

Electric Discharge Apparatus and the Process of Repairing the Same.

Mr. De Witt C. Tanner and Mr. John G. Roberts for Arnold.

Mr. Albert G. Davis and Mr. Alexander D. Lunt for Langmuir.

This is an appeal by Arnold from the decision of the examiner of interferences awarding priority to Langmuir, the senior party.

The invention in issue is a thermionic tube that is adapted to be used as a relay in long distance telephone

systems, as a detector or amplifier in wireless systems, or as a rectifier of alternating currents. Other uses are referred to, as in the case of the Coolidge X-ray tube; but the counts, except 13, are for the tube *per se* irrespective of its uses.

Structurally considered, the tubes of both parties are, or may be, substantially identical with the Fleming Valve or with the DeForest Audion. But these prior art devices are not within the issue, for the reason that they do not exhibit the characteristics required by the counts.

Considerable difficulty has been experienced in formulating a satisfactory issue. After consideration of a motion to dissolve and motions to amend, and after the admission of two new counts (12 and 13) by stipulation, the issue stands with thirteen counts, of which the following are sufficiently illustrative:

1. A high vacuum electron discharge device comprising an envelope, an incandescent cathode, and an anode, the space in said envelope being evacuated to such degree that the passage of current produces no appreciable positive ionization when the impressed voltage is as high as 200 volts.

5. A discharge tube having electrodes at least one of which is adapted to emit electrons, the gas content or residue of said tube and the relation of the parts of the tube being such that the tube is capable of being so operated in a range below saturation and materially above ionization voltages that in that range the space current is governed by the combined effect of the electric field of said electrons and the potentials applied to said electrodes, the governing or limiting the current being substantially unaffected by positive ionization and by secondary electron emission from the walls of the tube.

7. A discharge device comprising a tube and electrodes therein one of which is adapted to emit electrons, the degree of evacuation and the relation of the parts of the device being such that the device is capable of being so operated, when voltages materially higher than ionization voltages are impressed on electrodes of the device and when the electron emission has any value such that the space current is below the saturation region at such voltages, that the line obtained by plotting the logarithms of any values of said current below the saturation region as ordinates against the logarithms of the corresponding values of said impressed voltages as abscissae is straight and continuous.

9. A discharge device comprising a tube and electrodes therein one of which is an electron emitting cathode, the degree of evacuation of said device and the relation of the parts of the device being such that the device is capable of being so operated, when voltages materially higher than ionization voltages are impressed on electrodes of the device and when the electron emission is such that the space current is below the saturation region at such voltages, that said current is substantially independent of the cathode temperature and unaffected by secondary electron emission from the walls of the tube.

11. A discharge tube having a cathode adopted to emit electrons, an anode adapted to receive electrons and tube walls fashioned or shaped so as to permit the free passage of a useful proportion of said electrons from cathode to anode, the gas content or residue of said tube and the relation of the parts of the tube being such that the tube is capable of operation with stable and reproducible results substantially unaffected by positive ionization, with currents of at least 5 milliamperes and with voltages of at least 200 volts.

13. The method of controlling an electric current in one circuit by an electromotive force in another circuit which consists in causing said current at voltages materially above ionization voltages to pass as a discharge across a vacuous space between an electron emitting cathode and an anode, maintaining a high vacuum in said space, governing or limiting the current by a space charge effect in said space substantially unaffected by positive ionization, and superimposing the effect of said electromotive force on said space charge effect to control said current in a stable and reproducible manner.

The invention has been referred to as a "thing compact of glass and metal." That description is correct as far as it goes, but that it is inadequate is evident from the fact that it applies equally well to the prior art devices. If it were qualified by the statement that it operates with a *pure* electronic discharge above the voltage of positive ionization and below saturation, it would, at least, be improved. But how is one to know whether the discharge is purely electronic? In other words, how is one to know whether a tube embodies merely the prior art devices or the invention in issue? A thermionic tube which operates solely by electron discharges or currents has certain distinctive characteristics by means of which the presence of the invention may be recognized, and the counts have been so worded that each brings out one or more of these characteristics. For example, count 1 specifies that the envelope of the tube is evacuated to such a degree that the passage of current produces no appreciable positive ionization when the impressed voltage is as high as 200 volts. Thus the count distinguishes from the prior art, not by features of structure, but by a characteristic which is manifest while the device is operating at or above a certain voltage. The audion is not evacuated

to the high degree that count 1 calls for and, at an impressed voltage of about 30, ionization occurs. Count 5 specifies that the relation of the parts of the tube and the degree of evacuation are such that, when operated in a range below saturation and materially above ionization voltages, the space current is governed by the combined effect of the electric field of the electrons and the potentials applied to the electrodes, the governing or limiting of the current being substantially unaffected by secondary electron emission from the walls of the tube.

When a thermionic tube is operating by a pure electronic discharge at a voltage substantially below saturation, the current varies in substantial accordance with the 3/2 power of the impressed voltage. If the voltages be plotted as abscissae and the currents as ordinates, the result is a curve that gradually rises and turns toward the left—the curve of the 3/2 power. This obtains while there are plenty of electrons emitted from the cathode, at the temperature at which it is heated, to make up the increasing current. But the number of electrons emitted varies with the temperature of the cathode and that temperature is generally maintained constant. Consequently, a voltage will be reached which is capable of forcing the electrons across the space more rapidly than they can be emitted. The result is the flat-topped curve showing saturation. The tubes of the issue are operated at voltages above that of ionization and below that of saturation, and the voltage current curve follows the 3/2 power law. This is one of the characteristics of the tubes; and a tube that has such a characteristic operates by a pure electrode discharge and is a tube of the issue.

Ionization occurs when there is gas within the tube during operation. This gas may be normally free, as when mercury vapors are present, or it may be absorbed or

occluded in the electrodes, particularly the anode, and in the glass walls of the tube. The electrodes and walls act like sponges, taking up the gas when cold and again giving it off when heated during operation. A tube which has gas either in a normal free state or occluded in the electrodes or walls is subject to ionization; and ionization takes place when the voltage rises sufficient to produce it. About 15 volts is sufficient to give this result. But a tube which operates by ionizing a gas does not respond to the 3/2 power law and is not a tube of the issue. Excessive ionization is usually accompanied by a blue glow or haze; but such a glow is not a reliable test, as both parties admit, since a tube that does not show blue glow may produce ionization to such a degree as to cause it to depart from the 3/2 power characteristic.

Any tube which gives the 3/2 power voltage-current curve must also give the straight-line when the volts and current are plotted on logarithmic paper. These two curves are plotted from the same data and their differences are due simply to the difference in the arrangement of the lines on the paper. If, therefore, the volts and currents be plotted on one kind of paper and the result shows a pure electron discharge, there can be no doubt what the other kind of paper would show. Certain counts, as 6 and 7, call for the straight-line, while count 8 calls for the 3/2 power characteristic.

Other counts refer to the electric field of the electrons (count 2) or to space current due to the electric field of the electrons (count 3). The electrons are supposed to be exceedingly minute pieces of negative electricity, and they react on one another just like a flock of pith balls would react if they were confined in some manner so that they were each within the field of influence of the others. If they were all charged with negative electricity and there

were no available positive charges to neutralize them, they would simply create an electric field or space charge. But if at one part of this field a positive charge were created, the negatively charged pith balls would fly across the field to it, thus setting up a current. That is what happens in the tubes of the issue. The electrons are generated or emitted by the heated cathode; and if there is no way of neutralizing them they simply fill the space, charge it negatively and react on one another. But if the anode be charged positively, the electrons fly across the field to it and become neutralized. This flow of electrons is a current; and, assuming a sufficient emission of electrons, the strength of the current is dependent on the potential difference between the cathode and anode. If this difference is small, comparatively few electrons get through and the others continue to react on one another. If no gas be present in the tube, either free or occluded, the current is governed by the electric field of the electrons and the potential applied to the electrodes. If gas is present and the voltage is above ionization, some of the gas molecules become ionized and rendered positive by having one or more of their negatively charged electrons knocked out of place. These positively charged molecules or ions remain in the field a relatively long time and increase the flow of the electrons. This increases the current more rapidly than the pure electron current would increase and so deviates from the 3/2 power law. This explains the meaning of such counts as 2 to 5, inclusive.

The degree of ionization in a tube varies with the quantity of gas therein. Generally when ionization occurs the current at a given voltage is larger than it would be at that voltage were no appreciable ionization present. If, therefore, a tube containing some gas were operated and the vacuum therein were gradually increased, as by a

pump, the voltage remaining constant, the current would drop as the vacuum improved until ionization became substantially negligible, when the drop in current would cease. This is a test of the invention as defined in such counts as 2 and 3.

The character of the electron discharge is affected by the relation of the parts of the tube. When the passage for the electrons is long, narrow or crooked, the electrons strike the walls of the tube and adhere thereto. This is exemplified by the Lilienfeld experiments in which a long, crooked, capillary-like tube was employed. Only a very minute current was obtained although thousands of volts were employed. Furthermore, it is not possible to remove all the gas, and, when the passage for the electrons is restricted, ionization takes place even in a very high vacuum. Such counts as 5, 8 and 9 call for such a "relation of parts" as render the tube capable of producing a current governed by the combined effect of the electric field of the electrons and the potential applied to the electrodes. Count 9 further states that the current is substantially unaffected by secondary electron emission from the walls of the tube. When the walls are long, crooked or narrowly spaced, the electrons adhere to them, as stated, until they are knocked loose by the electrons of the primary discharge. When thus set free, they constitute a secondary electron emission. The count further states that the current is substantially independent of the cathode temperature. According to Richardson's Law, which is extensively discussed in the records, the electron emission from the cathode increases with the temperature of the latter. But the number passing to the anode, in a tube of the issue, depends upon the impressed voltages. If at a given cathode temperature there are sufficient electrons to furnish the current at the voltage used, an in-

crease of temperature and an increase of electron emission will not increase or otherwise affect the current. Under such conditions, the current is substantially independent of the cathode temperature.

Counts 12 and 13 are the only ones that call for the third electrode. This electrode is generally referred to as the "grid." It is placed between the cathode and anode; and when an electromotive force is applied to it, it modifies the electric field and controls the current passing to the anode. When there is no ionization, this control is certain and the variations in the current follow proportionately and in a reproducible manner the variations of the electromotive force applied to the grid.

The invention in issue is, therefore, a thermionic tube that operates with a pure primary and substantially no secondary electronic discharge at voltages above ionization and below saturation; and such a tube is to be recognized by its response to the characteristics expressed in the several counts. The tubes of counts 12 and 13 have three electrodes, while those of counts 1 to 11 may have two or more, these counts being generic.

The question for us to determine is who, of the parties involved, first knowingly and understandingly conceived and produced such a tube. This brings us to a consideration of the testimony.

Arnold, the junior party, does not claim to have conceived the invention prior to November 1, 1912, or to have reduced it to practice prior to the 29th of that month. On the other hand, Langmuir alleges conception, disclosure, sketches, written description and successful operation prior to September 1, 1912, followed by the successful operation of other devices embodying the invention in November, 1912. Arnold's testimony, as does his preliminary statement, limits his activities with respect to

the invention to a period beginning November 1, 1912. If, therefore, Langmuir has established conception prior to that date and reduction to practice prior to November 29, 1912, or conception prior to November 1, 1912, with due diligence leading up to a subsequent reduction to practice, either actual or constructive, he must prevail, and it will, in that event, be unnecessary to make a detailed analysis of Arnold's proofs. We will, therefore, first take up a consideration of Langmuir's case. Before doing so, however, we wish to state, in a general way, our views as to what constitutes conception or reduction to practice of the invention.

If one, working in some "useful" art, produces a device which is new, of practical utility and such as is unobvious to those skilled in that art, he has made an invention; and it is immaterial that he may not, at the time foresee all its uses, or understand the scientific principle underlying it. He must, however, know that it has some practical utility and must be able to teach those skilled in the art how the device may be reproduced and how it may be used to accomplish some practical and useful result. If he simply notes that it behaves in some novel and characteristic fashion under certain conditions, but has no idea as to how it can be used to accomplish some practical result in relation to the useful arts, he has not gone far enough to entitle himself to a patent. He is purely an investigator. When he has discovered how his device may be made of some practical use, he has completed the inventive act. Further, if in the course of his experimentation, he actually makes a new, useful and unobvious thing but does not know it, or, knowing it, does not know how he did it, he cannot teach others how to make and use the thing. Consequently, he has added nothing to the sum of practical knowledge and has made no invention.

Langmuir's application herein involved is assigned to the General Electric Company, by which he is employed. This Company has an extensive research laboratory which is thoroughly equipped for scientific experimentation. In this laboratory Langmuir did his work. He had an assistant named Sweetser.

It appears, particularly from the record on the motion, that prior to the production of the present invention, Langmuir was familiar with the so-called Edison effect and the Fleming valve and knew that an electron current passed from the heated cathode to the anode in an exhausted tube when potential was applied. He also knew that this current was modified by the presence of gases and that the gases could be eliminated, at least in part, by heat, as by lighting the filaments. This was known as the "clean-up" effect. In the first part of 1912 Sweetser was investigating this effect, and Langmuir kept in close touch with and directed his work. Some devices were made and tested that Langmuir contends embodied the invention in issue and were reductions to practice. It is clear that great care was observed in the preparation of these devices particularly in the heat treatment of the glass and the electrodes, and that charactristics approximating those of the issue were observed. Langmuir had been working on gas-filled lamps for some time, and the tests in August, 1912, had special reference to the clean-up of nitrogen in lamps. For this reason, presumably, nitrogen was introduced into the tube, which was then operated at voltages far above ionization. In the beginning of the run, when the gas pressure was highest, the thermionic current was 18 milliamperes. As the operation proceeded the pressure fell until it reached 1.08 microns without material reduction in current. But below that, the current fell off until, when the pressure

reached about .34 microns, the current become substantially constant at about 4.5 milliamperes. The results of the tests were tabulated by Sweetser in Langmuir's Exhibit No. 79. On page 103 of Langmuir's Priority Record is a plot made from Sweetser's data which shows that the current and voltage followed approximately the 3/2 power law. At the time of these tests, however, Langmuir was not familiar with this law.

The August, 1912, experiments were made with a specially prepared thermionic tube which was operated at voltages above that of ionization and below saturation. There was no blue glow and the results showed a close approximation to the 3/2 power law, which is one of the characteristics of the tubes of the issue. But apparently it was an approximation only. However, we cannot agree with the examiner of interferences that Langmuir had no conception of the invention as defined in counts 1 to 11. It is true he did not then forsee all of the marvelous possibilities of the device; but he certainly had in mind a thermionic tube having such a relation of parts and such a degree of vacuum therein that there should be no ionization at 200 volts and in which the space current should be as high as 5 milliamperes. He also knew how to make such a device. If at that time he had been called upon to define the tube he had in mind he would not have employed such terms as space charge, 3/2 power law and logarithmic plot as were subsequently adopted when the counts of the issue were formulated. But these things are not the invention. They are simply characteristics of the invention—ear-marks by which the invention may be recognized. If Langmuir had in mind a tube that would operate with a pure electron discharge at voltages above ionization and below saturation and knew how to produce it, he had the invention in mind. We therefore hold that

he is entitled to a date not later than the first of September, 1912, for conception of the invention as defined in counts 1 to 11, inclusive.

In November, 1912, Langmuir prepared three tubes with extraordinary care. They had been made some time before for another purpose but had not been used. No doubt they were selected because of the peculiar arrangement of the filament which was in three sections with four separate leads. Current could be passed through any section singly, through any two adjacent sections or through all sections in series. A two filament tube could be produced only by burning out or otherwise destroying the middle section. The tube was exhausted mechanically to a high vacuum, after which the middle section of the filament was vaporized by running an abnormally high current through it. This had the effect not only of making two electrodes, but of cleaning up the tube and increasing the vacuum to a higher degree than had been obtained before. We cannot doubt that this method was adopted for the express purpose of denuding the tube of all gases that might produce ionization when high voltages were employed.

The tubes thus prepared were tested and the results tabulated. (Langmuir Ex. #81, pages 124 *et seq.*). 250 volts were applied. The cathode was heated increasingly from 1730° to 3320° K. The current increased with the temperature at first, then fell behind and finally became constant. On November 20, 1912, Langmuir wrote in his notebook (p. 126 of Exhibit #81):

> "The Edison current does not increase indefinitely with the temperature but reaches a max. value at about 2700° at which it remains constant. It is roughly proportional to the voltage at the anode."

Again on page 130 he wrote:

> "With the first few runs there was a slight tendency for the Edison current at any given temperature to increase except with very high temperatures. At those very high temperatures the current was absolutely constant (independent of the temperature) and surprisingly independent of all external conditions of gas pressure, temperature of bulb, etc. This limiting current was approximately proportional to the voltage at anode and to area of anode."
>
> "After several runs quite consistent results were obtained on repeating."

This showed that no positive ionization was taking place, and that the discharge was purely electronic. Such a discharge was just what Langmuir was attempting to produce, and he succeeded. It does not seem to us material that Child had previously discussed the phenomenon that Langmuir actually observed. As Arnold admits (brief, page 115), Child made no application of the scientific principal he had discussed. But Langmuir did. He produced a tube which was operated at voltages far above any previously employed in thermionic tubes and obtained a current and an output correspondingly high. As he knew how he did it, he undoubtedly could have done it again and as often as he desired. We can perceive no ground that appears reasonable for holding that the tubes of November, 1912, were not reductions to practice of the invention of counts 1 to 11, inclusive, if Langmuir then knew they had practical utility. He was familiar with the Fleming Valve and of its uses. Certainly it must have been clear to him that his improved valve, with its possibility of use at high voltages and with an output of several watts, had utility. The tests of the tubes which dem-

onstrated the presence of the invention were made on November 19, 1912, and Langmuir is entitled to that date for actual reduction to practice of the invention of counts 1 to 11 inclusive. This holding is made notwithstanding the fact that Langmuir did not at the time test the tubes to determine whether they followed the 3/2 power law or gave a straight-line on a logarithmic plot. As a matter of fact, Langmuir did not work out the mathematical theory of the space charge effect or derive the 3/2 power law until the following February. (Langmuir's Brief, page 153). But any tube built as these tubes were and exhausted to the degree that would prevent ionization at 250 volts would necessarily have responded to the various tests called for in the counts.

It seems logical to discuss at this point Arnold's contention that Langmuir has introduced new matter into his application. On page 15 of his brief Arnold copies count 4 as typical and sets it down in clauses *a* to *f*, clauses *c* and *e* being as follows:

(*c*) the gas content or residue of said tube and the relation of the parts of the tube being such that the tube is capable of being so operated in a range below saturation.

* * * * * * * *

(*e*) that the space current is governed or limited by the electric field of said electrons."

These two clauses, Arnold contends, are new matter in Langmuir's case. We do not so regard them. They are merely statements which are descriptive of the invention which is otherwise disclosed. When one fully describes an invention and its uses and it subsequently occurs to him, or he subsequently discovers, that it has some inherent characteristic that he had not pointed out in his original specification, an amendment setting forth this

characteristic does not change or add to the invention and is not objectionable as new matter. Nor is it objectionable to include this inherent characteristic in his claims in order to point out his invention and distinguish it from prior art devices. It is our view that the characteristic referred to in Arnold's clauses *c* and *e* is inherent in the thermionic tube Langmuir had fully disclosed and that the description of the same and its inclusion in some of the counts does not import new matter into the application.

This brings us to a consideration of count 12, which is for the three electrode device, and 13, which is for the method of controlling an electric current in that kind of device. They are distinguished from the DeForest audion by the high vacuum and the space charge effect, as are certain of the other counts previously discussed.

Langmuir alleges conception, disclosure, drawings, written description and reduction to practice of the invention of these counts in the period between February 1 and March 15, 1913. These are later than the corresponding dates alleged by Arnold.

While experimenting in November, 1912, Langmuir noticed that the Edison current was affected by the presence of a spark coil or oscillator or by touching the bulb with the fingers. (Langmuir Ex. #81, pp. 135 and 136.) At the bottom of page 127 of his brief Langmuir suggests that this demonstrated the possibility of controlling a current of 250 volts by an electric field and by a principle which is the same as that employed by the three filament tubes. But three electrodes were not then employed or suggested, and there is nothing to indicate that Langmuir regarded the phenomenon he had observed as of any practical value. In any event he can be accorded no date of conception earlier than that alleged.

There is considerable discussion in the Langmuir Records, as well as in the briefs of both parties, of a recorded discussion between Langmuir and Dr. Coolidge respecting the latter's X-ray tube, and Langmuir contends that he reduced counts 12 and 13 to practice with a specially constructed and operated tube of that nature. In the view that we take of this matter it becomes unnecessary for us to pass upon the merits of this contention or upon Arnold's objection to the testimony respecting the X-ray tube.

In February, 1913, Langmuir disclosed and demonstrated the invention of counts 1 to 11, inclusive, to one White, who was another assistant in the Research Laboratory. A tube was then operated at 50 volts while the cathode temperature was increased from a dull red to full incandescence, and White was shown how the electron current increased with the temperature up to a certain point beyond which it became substantially constant. This showed that no ionization was taking place. He was then shown that at a constant temperature of the cathode and an increase of voltage from a low value the current became substantially constant at about 100 volts although the voltage was increased to about 200 (Langmuir Record on Motion, p. 597). Langmuir learned of the DeForest audion sometime about November, 1912; and, at the time of the demonstrations to White, he told the latter that he would procure an audion for him to test. Shortly thereafter an audion was turned over to White who subjected it to the same tests that Langmuir had employed at the earlier demonstration. When he used 50 volts and raised the temperature of the cathode the current did not become stationary, but a blue glow appeared. The results were not reproducible. He then took a three electrode tube that Langmuir had designed,

and exhausted it to within a fraction of a micron. He then baked the tube for several hours at a temperature just below the maximum that the glass would stand without softening. He then heated the filament for some time above normal and then operated the plate as a filament. The grid and plate were then subjected to electron bombardment at currents and voltages higher than those under which they were designed to operate, and no blue glow or fluorescence appeared. The tube was then sealed, was tested as a relay, and White found that he

> "could get a good control of the plate current by means of the grid voltage, varying it from several volts negative to several volts positive and using voltages of over 100 on the plate."
>
> (Q17, Langmuir's Record on Motion, p. 602.)

It seems that Langmuir must have had a conception of the invention of counts 12 and 13 in the first half of February, 1913, since he made the demonstrations to White prior to the middle of that month. White fixes this date by an accident to himself which kept him out of the laboratory for about two weeks. However, it is not important that the exact date of conception be fixed, since one of the tubes White had made and tested was turned over to one Dushman on April 8, 1913, for use in measuring very small electric currents. On page 143 of Langmuir's Priority Record Dushman quotes from his notebook No. 464 as follows:

> "Langmuir gave me Audion No. 2 for use in these experiments, also White gave me calibration curve giving relation between Plate EMF and grid EMF for different currents."

He then says:

> "The main difficulties encountered in using the audion were those due to a lack of proper resist-

ance. In order to obtain the best amplification with the audion, it was necessary to have a nice adjustment between the resistance used in the plate and grid circuits, and the determination of this adjustment consumed a great deal of time. Finally, I did succeed in obtaining very satisfactory results. On these experiments I used voltages up to 240 on the plate of the audion and obtained perfectly reproducible and constant results. There was no evidence of blue glow or any erratic behavior which would indicate positive ionization in the bulb."

Respecting these experiments, Langmuir wrote in his notebook No. 458, page 60 under date of April 15, 1913:

"Dushman has been using our Tube 2 for magnifying the current of his photo electric cell. He had no trouble getting 1,000 fold magnification and at one time for a couple of hours he found beautiful proportionality between the original current and the magnified current. Later he could not reproduce these conditions."

It appears from Dushman's statement that the troubles were probably due to lack of proper resistances or to leakage somewhere outside the tube and not to the tube itself.

As before the examiner of interferences, Arnold objects to the evidence respecting Dushman's experiments with Audion No. 2 on the ground that, the contemporaneous records not being produced, the oral testimony of the witnesses is not the best evidence. We agree with the reasoning and the conclusion of the examiner of interferences as to this contention and further discussion of the same is deemed unnecessary. It may be pointed out, however, that the production of said records, the existence of which

was admitted (White, XQ137, p. 655 of Langmuir's Record on Motion), was not requested and was not refused. Arnold's statements that they were suppressed is therefore considered unwarranted.

In view of all the above, we find that Langmuir had conceived the invention of counts 1 to 11, inclusive, at least as early as September 1, 1912, and had reduced the same to practice by November 19, 1912. As to counts 12 and 13, he had conceived certainly prior to April 8, 1913, and had reduced to practice by April 15, 1913.

Little need be said on the other side of the case as respects counts 1 to 11, since Arnold does not allege conception and reduction to practice until after the corresponding dates we have awarded to Langmuir. Consequently, Langmuir is entitled to prevail as to these counts for the reason that he was the first to conceive and the first to reduce. Counts 12 and 13, however, call for some consideration of Arnold's proofs.

In 1911 the American Telegraph and Telephone Company and the Western Electric Company were building a transcontinental telephone line, for which they required a better repeater than any that was then available. The latter company, which is the assignee of the Arnold application, employed Arnold to develop for it a repeater that would meet its needs. Arnold conceived the idea of employing the mercury arc, and, by 1912, he had done considerable work in the way of developing a repeater of that type. In the latter part of October, 1912, Dr. DeForest demonstrated his audion to Dr. Jewett and Mr. Colpitts in the laboratory of the Western Electric Company. Arnold was not present at this demonstration; but, on November 1, 1912, he was called in and the same was repeated. The audion appeared to amplify feeble sounds, but broke down and showed blue haze when louder sounds were

employed. Furthermore, its available output—said to be less than six milliwatts—was entirely too small for a telephone repeater. According to the testimony, Arnold at once perceived just where the troubles lay, and then and there disclosed the invention in issue to Colpitts and Jewett. He pointed out the necessity of a high vacuum and explained the space charge effect (Colpitts, p. 74 Arnold Priority Record). Jewett testifies (p. 65, same record):

> "Dr. Arnold said that he could make a tube like these DeForest audions but with greater electron emission and so much better evacuated that erratic behavior due to positive ionization would be eliminated, and the device could be operated at the higher voltages necessary for telephone repeater service without sacrifice of its favorable operational features."

According to this testimony, Arnold had a conception of a thermionic tube so thoroughly evacuated that it would have a pure electron discharge; and if it clearly appears that he knew how to produce such a tube we would consider him entitled to November 1, 1912, for conception of the invention in issue. But we are not satisfied that he had such knowledge, and his subsequent acts indicate that he did not have. Unless he could produce the device of the issue and could teach others how to produce the same, he had not a complete conception. Colpitts says (p. 72, Arnold Priority Record) that

> "Arnold assured us that the 'blue haze' and the accompanying erratic and noisy behavior could be overcome by eliminating the residual gas from the tube by methods of heat treatment and pumping with which he had become familiar in his previous work and study."

But he does not say what was to be given the heat treatment, for how long a time or at what temperature. In our consideration of Langmuir's work in August, 1912, we refused to give him a reduction to practice although the heat treatment and pumping had actually been carried on to a high degree. Certainly, the mere suggestion of the employment of a heat treatment and pumping is insufficient to show that Arnold knew how to carry out such treatment to secure the results he had in mind.

On November 16, 1912, Arnold set his assistant Pierce to work determining the characteristics of the audion. One of the filaments of audion No. 7 was burned out on November 29, 1912, and this, of course, improved the vacuum. But this was not done with a purpose and if Arnold knew what had been the effect he apparently failed to appreciate it. In any event, it was not subsequently resorted to, although it was a simple process and one that would seemingly have made the Gaede pump unnecessary. But this pump was ordered from Germany some months later and was received in the spring of 1913. It was used on April 25, 1913, to evacuate audion No. 20.2. Respecting this operation Arnold testified (p. 50, Priority Record):

> "These tests with the molecular pump were not undertaken by me as tests of the operableness of a high vacuum tube. Of that there had been no doubt in my mind. They were merely tests of the usefulness of the Gaede molecular pump in helping us to attain the high vacuum required. With it thus established that the Gaede pump was capable of producing the required high vacuum repeater tubes, and that they would stand up in service, I ceased to concern myself with this phase of the matter and left the evacuation of devices from that time on in the hands of our laboratory assistants."

This seems to us an admission by Arnold that, prior to April 25, 1913, he was merely speculating on ways and means for securing the vacuum in the tubes necessary for producing the pure electron discharge. Prior to that date, therefore, Arnold had no complete conception of the invention in issue, since he did not know whether the necessary vacuum could be attained.

The examiner of interferences has held that Arnold reduced to practice the invention of counts 2 to 5, inclusive, 9, 10, 12 and 13 on April 25, 1913 when he tested tube 20.2. The data regarding this test are recorded on page 105 of Pierce's notebook (Arnold Exhibit No. 18) and are plotted on Sketch No. E. S. 86907 (Exhibit No. 19). This plot is somewhat puzzling. The long full-line curve seems to follow some power law up to about 24 volts, then to bend over slowly to the right to about 40 volts after which it bends rapidly in the same direction, indicating saturation. But, instead of the current becoming constant under increased voltages, it rapidly drops until at about 210 volts it is but a little more than 3.5 milliamperes where it remains substantially constant up to 240 volts. When, thereafter, the voltage was lowered, the current at once fell and its curve by no means reproduced the curve obtained with the increasing voltages until the 24 volts was again reached. Apparently, therefore, the results were not reproducible except below 24 volts. During this test the filament current was 69 amperes. When the same tube was tested with a filament current of .64 amperes the results were much the same, the ascending and descending-voltage curves coinciding only below 16 volts. Those parts of both curves where reproducible results were apparently obtained do not follow the 3/2 power law, being much too steep. This seems to indicate ionization. If the 3/2 power law is an

accurate test of the presence of the invention of the issue, as the parties agree, then Arnold's 20.2 tube did not embody the issue. However, the same exhibit (No. 19) shows a plot in dotted lines of Audion B which appears to follow substantially the 3/2 power law and which indicates substantial reproducibility up to 100 volts. The data from which this plot was made was obtained April 25, 1913, and recorded on page 107 of Pierce's Notebook (Exhibit No. 18). In view of this data and plot, we find that Arnold conceived and reduced to practice the invention of all the counts except 1 and 11 on April 25, 1913. As to these two counts, we agree with the examiner of interferences that they were not reduced to practice until after Langmuir's filing date.

As to all the counts, therefore, Langmuir was the first to conceive and the first to reduce. The decision of the examiner of interferences awarding priority to Langmuir is accordingly affirmed.

Limit of Appeal: May 11, 1923.

S. E. Fouts,
R. E. Marine,
E. S. Henry,
Examiners-in-Chief.

Opinion of Assistant Commissioner of Patents.

October 27, 1923.

(Interference Record p. 2509.)

IN THE UNITED STATES PATENT OFFICE.

Patent Interference No. 40,380.

ARNOLD

v.

LANGMUIR.

Appeal from Examiners-in-Chief.

Electric Discharge Apparatus and the Process of Preparing the Same.

Application of Harold De Forest Arnold filed November 2, 1915, No. 59,210.

Application of Irving Langmuir filed March 14, 1916, No. 84,242, for renewal of application filed October 16, 1913, No. 795,610.

Messrs. De Witt C. Tanner and John G. Roberts and Mr. Geo. E. Folk for Arnold. Mr. Carl A. Richmond of counsel.

Mr. Albert G. Davis and Mr. Alexander D. Lunt for Langmuir.

This is an appeal by Arnold from a decision of the examiners-in-chief affirming the examiner of interferences awarding priority on all counts to Langmuir.

The issue is a thermionic tube in which there may be a pure electron discharge as distinguished from a discharge through gas which is ionized, so as to be useful for such

purposes as a telephone relay, a wireless detector or amplifier, a rectifier of alternating current and possibly a generator of X-rays. It is the device of defendant in Hewitt *v.* American T. and T. Co., 272 Fed. Rep., 194, and 272 Fed. Rep., 392. The invention is exemplified by a structure such as the well known De Forest audion or Fleming Valve (see Marconi Co. *v.* De Forest Co., 236 Fed. Rep., 942), modified so that there is present during operation too little gas to modify or affect the pure electron discharge from the cathode.

The applications were filed in 1913 (renewed in 1916) and 1915. After the interference was declared, Arnold moved to dissolve on the ground that the issue was unpatentable. In February, 1917, the Commissioner ordered testimony to be taken on the question of patentability and between July, 1917, and January, 1920, over 1,650 printed pages of testimony accompanied by a great mass of exhibits were introduced. Much of this testimony should not have been taken since it related to priority alone. Motions were made to amend the issue and some counts were withdrawn. The law examiner rendered a seventeen page opinion settling the counts and finding patentability. Subsequently, by stipulation, other counts were added and the issue fixed into thirteen counts, of which the following are sufficiently illustrative:

1. A high vacuum electron discharge device comprising an envelope, an incandescent cathode, and an anode, the space in said envelope being evacuated to such degree that the passage of current produces no appreciable positive ionization when the impressed voltage is as high as 200 volts.

5. A discharge tube having electrodes at least one of which is adapted to emit electrons, the gas content or

residue of said tube and the relation of the parts of the tube being such that the tube is capable of being so operated in a range below saturation and materially above ionization voltages that in that range the space current is governed by the combined effect of the electric field of said electrons and the potentials applied to said electrodes, the governing or limiting of the current being substantially unaffected by positive ionization and by secondary electron emission from the walls of the tube.

7. A discharge device comprising a tube and electrodes therein one of which is adapted to emit electrons, the degree of evacuation and the relation of the parts of the device being such that the device is capable of being so operated, when voltages materially higher than ionization voltages are impressed on electrodes of the device and when the electron emission has any value such that the space current is below the saturation region at such voltages, that the line obtained by plotting the logarithms of any values of said current below the saturation region as ordinates against the logarithms of the corresponding values of said impressed voltages as abscissæ is straight and continuous.

9. A discharge device comprising a tube and electrodes therein one of which is an electron emitting cathode, the degree of evacuation of said device and the relation of the parts of the device being such that the device is capable of being so operated, when voltages materially higher than ionization voltages are impressed on electrodes of the device and when the electron emission is such that the space current is below the saturation region at such voltages, that said current is substantially independent of the cathode temperature and unaffected by secondary electron emission from the walls of the tube.

11. A discharge tube having a cathode adapted to emit electrons, an anode adapted to receive electrons and tube walls fashioned or shaped so as to permit the free passage of the useful proportion of said electrons from cathode to anode, the gas content or residue of said tube and the relation of the parts of the tube being such that the tube is capable of operation with stable and reproducible results substantially unaffected by positive ionization, with currents of at least 5 milliamperes and with voltages of at least 200 volts.

13. The method of controlling an electric current in one circuit by an electromotive force in another circuit which consists in causing said current at voltages materially above ionization voltages to pass as a discharge across a vacuous space between an electron emitting cathode and an anode; maintaining a high vacuum in said space, governing or limiting the current by a space charge effect in said space substantially unaffected by positive ionization, and superimposing the effect of said electromotive force on said space charge effect to control said current in a stable and reproducible manner.

The counts are ably and clearly analyzed by the examiners-in-chief thus:

A thermionic tube which operates solely by electron discharges or currents has certain distinctive characteristics by means of which the presence of the invention may be recognized, and the counts have been so worded that each brings out one or more of these characteristics. For example, count 1 specifies that the envelope of the tube is evacuated to such a degree that the passage of current produces no appreciable positive ionization when the impressed voltage is as high as 200 volts. Thus the count distinguishes from the prior art, not by features of

structure, but by a characteristic which is manifest while the device is operating at or above a certain voltage. The audion is not evacuated to the high degree that count 1 calls for, and at an impressed voltage of about 30, ionization occurs. Count 5 specifies that the relation of the parts of the tube and the degree of evacuation are such that, when operated in a range below saturation and materially above ionization voltages, the space current is governed by the combined effect of the electric field of the electrons and the potentials applied to the electrodes, the governing or limiting of the current being substantially unaffected by secondary electron emission from the walls of the tube.

When a thermionic tube is operating by a pure electronic discharge at a voltage substantially below saturation, the current varies in substantial accordance with the 3/2 power of the impressed voltage. If the voltages be plotted as abscissas and the currents as ordinates, the result is a curve that gradually rises and turns toward the left—the curve of the 3/2 power. This obtains while there are plenty of electrons emitted from the cathode, at the temperature at which it is heated, to make up the increasing current. But the number of electrons emitted varies with the temperature of the cathode and that temperature is generally maintained constant. Consequently, a voltage will be reached which is capable of forcing the electrons across the space more rapidly than they can be emitted. The result is the flat-topped curve showing saturation. The tubes of the issue are operated at voltages above that of ionization and below that of saturation, and the voltage current curve follows the 3/2 power law. This is one of the characteristics of the tubes; and a tube that has such a characteristic operates by a pure electronic discharge and is a tube of the issue.

Ionization occurs when there is gas within the tube during operation. This gas may be normally free, as when mercury vapors are present, or it may be absorbed or occluded in the electrodes, particularly the anode, and in the glass walls of the tube. The electrodes and walls act like sponges, taking up the gas when cold and again giving it off when heated during operation. A tube which has gas either in a normal free state or occluded in the electrodes or walls is subject to ionization; and ionization takes place when the voltage rises sufficiently to produce it. About 15 volts is sufficient to give this result. But a tube which operates by ionizing a gas does not respond to the 3/2 power law and is not a tube of the issue. Excessive ionization is usually accompanied by a blue glow or haze; but such a glow is not a reliable test, as both parties admit, since a tube that does not show blue glow may produce ionization to such a degree as to cause it to depart from the 3/2 power characteristic.

Any tube which gives the 3/2 power voltage-current curve must also give the straight-line when the volts and current are plotted on logarithmic paper. These two curves are plotted from the same data and their differences are due simply to the difference in the arrangement of the lines on the paper. If, therefore, the volts and currents be plotted on one kind of paper and the result shows a pure electron discharge, there can be no doubt what the other kind of paper would show. Certain counts, as 6 and 7, call for the straight-line, while count 8 calls for the 3/2 power characteristics.

Other counts refer to the electric field of the electrons (count 2) or to space current due to the electric field of the electrons (count 3). The electrons are supposed to be exceedingly minute pieces of negative electricity, and

they react on one another just like a flock of pith balls would react if they were confined in some manner so that they were each within the field of influence of the others. If they were all charged with negative electricity and there were no available positive charge to neutralize them, they would simply create an electric field or space charge. But if at one part of this field a positive charge were created, the negatively charged pith balls would fly across the field to it, thus setting up a current. That is what happens in the tubes of the issue. The electrons are generated or emitted by the heated cathode; and if there is no way of neutralizing them they simply fill the space, charge it negatively, and react on one another. But if the anode be charged positively, the electrons fly across the field to it and become neutralized. This flow of electrons is a current; and, assuming a sufficient emission of electrons, the strength of the current is dependent on the potential difference between the cathode and anode. If this difference is small, comparatively few electrons get through and the others continue to react on one another. If no gas be present in the tube, either free or occluded, the current is governed by the electric field of the electrons and the potential applied to the electrodes. If gas is present and the voltage is above ionization, some of the gas molecules become ionized and rendered positive by having one or more of their negatively charged electrons knocked out of place. These positively charged molecules or ions remain in the field a relatively long time and increase the flow of the electrons. This increases the current more rapidly than the pure electron current would increase and so deviates from the 3/2 power law. This explains the meaning of such counts as 2 to 5, inclusive.

The degree of ionization in a tube varies with the quantity of gas therein. Generally, when ionization occurs the current at a given voltage is larger than it would be at that voltage were no appreciable ionization present. If, therefore, a tube containing some gas were operated and the vacuum therein were gradually increased, as by a pump, the voltage remaining constant, the current would drop as the vacuum improved until ionization became substantially negligible, when the drop in current would cease. This is a test of the invention as defined in such counts as 2 and 3.

The character of the electron discharge is affected by the relation of the parts of the tube. When the passage for the electrons is long, narrow or crooked, the electrons strike the walls of the tube and adhere thereto. This is exemplified by the Lilienfeld experiments in which a long, crooked capilliary-like tube was employed. Only a very minute current was obtained although thousands of volts were employed. Furthermore, it is not possible to remove all the gas, and, when the passage for the electrons is restricted, ionization takes place even in a very high vacuum. Such counts as 5, 8 and 9 call for such a "relation of parts" as render the tube capable of producing a current governed by the combined effect of the electric field of the electrons and the potential applied to the electrodes. Count 9 further states that the current is substantially unaffected by secondary electron emission from the walls of the tube. When the walls are long, crooked or narrowly spaced, the electrons adhere to them, as stated, until they are knocked loose by the electrons of the primary discharge. When thus set free, they constitute a secondary electron emission. The count further states that the current is substantially independent of the

cathode temperature. According to Richardson's Law, which is extensively discussed in the records, the electron emission from the cathode increases with the temperature of the latter. But the number passing to the anode, in a tube of the issue, depends upon the impressed voltages. If at a given cathode temperature there are sufficient electrons to furnish the current at the voltage used, an increase of temperature and an increase of electron emission will not increase or otherwise affect the current. Under such conditions, the current is substantially independent of the cathode temperature.

Counts 12 and 13 are the only ones that call for the third electrode. This electrode is generally referred to as the "grid." It is placed between the cathode and anode; and when an electromotive force is applied to it, it modifies the electric field and controls the current passing to the anode. When there is no ionization, this control is certain and the variations in the current follow proportionately and in a reproducible manner the variations of the electromotive force applied to the grid.

The invention in issue is, therefore, a thermionic tube that operates with a pure primary and substantially no secondary discharge at voltages above ionization and below saturation; and such a tube is to be recognized by its response to the characteristics expressed in the several counts. The tubes of counts 12 and 13 have three electrodes, while those of counts 1 to 11 may have two or more, these counts being generic.

The record on the motion and the accompanying exhibits were stipulated in for use on priority, and during 1921 and 1922, upwards of 300 additional pages of testimony were taken. Appeals were promptly taken in what seems to be an honest effort of the parties to hasten a final determination of the case.

The inventions and their development have taken place in the laboratories and shops of the Western Electric Company and the General Electric Company. The parties have had at their disposal unlimited aid, both personal and financial, for the development and investigation of the invention, as well as for the presentation of their cases here. This would lead us to hope and expect to find the issue clearly and simply presented for consideration. It seems, however, that both parties and their counsel have been overpowered with amazement at the abstruse scientific theories that may be evolved to account for the plain simple facts of operation of the invented device. The result is that we are presented here with 379 pages of brief by Langmuir, who has the favorable decision of the examiners-in-chief, and 281 pages by Arnold, in an endeavor, not to controvert that decision, but to show his own priority. Neither brief pays much attention to the decisions below, but both attempt to treat the matter *de novo*, so that this decision may follow the same procedure.

The line between the prior art and the issue is attenuated and if there is patentability, it must be as set out in the decision of the law examiner on the motion, and I do not understand either party to attack that decision here. Arnold alleges that when he made the invention, he thought he was following the prior art and not producing something patentable, and an undercurrent of that attitude seems to tinge his whole case. This is why he filed so late.

I do not find it necessary to go beyond the decision of the law examiner to determine patentability or to interpret the prior art which was elaborately presented to him. He refers to:

> Article by Fleming in Scientific American Sup., Jan. 20, 1906, p. 25,129;

Article by Deininger in the Annalen der Physik, IV, Vol. XXV, p. 288 (1908);

Article by Von Baeyer, Physicalische Zeitschrift for 1909, p. 168;

Article by Gehrts, Annalen der Physik 39, p. 995 (1911);

Article by Child in the Physical Review, Vol. 32, p. 448 (1911);

Articles by Lilienfeld, Annalen der Physik 32, p. 673 (1910); Physicalische Zeitschrift 9, p. 193 (1908);

J. J. Thomson's Conduction of Electricity Through Gases, pp. 222 to 227;

Shottky, Jahrbuch der Radio Activitat, Vol. 12, p. 147 (1915);

Shottky in Physikalische Zeitschrift, 15,526 (1914).

After quoting freely from Langmuir's specification, he says:

It is apparent after a review of the record that there is no single element which is broadly novel in the assemblage of elements making up an electron discharge device of the character defined in the issue. An evacuated tube having therein an incandescent electron-emitting cathode and an anode was old prior to the filing of Langmuir's application, and methods of attaining high vacua, sufficient to give a relatively pure electron discharge in a properly designed tube, were also well known and available to persons skilled in the art.

* * * * * * *

The suggestion that the alleged invention represents a mere difference in degree over the prior art loses its force in the presence of the results accomplished (Edison *v.* U. S. Co., 52 F. R. 300, 308; General Electric Co. *v.* Nitro Tungsten Lamp Co., 282 O. G., 195), and the allegation of no

invention is overcome by the presumption of invention in the transformation of laboratory experiments, and erratic and unstable devices into reliable, stable and successful commercial products (Marconi *v.* De Forest, 243 F. R. 560).

It will be seen then that the present invention lies not in discovering or producing something new, but in perceiving the practicability of scientific facts known in the laboratory and in making practical, useful devices embodying the scientific laws known in the laboratory.

I am struck throughout the record with the care, caution and integrity of the parties and the witnesses. The effort seems to be constantly present to be scrupulously accurate and truthful. The benefits of this are largely lost by the fact that much of the record is made up of sworn statements followed by very little cross examination, some of which is by similar statements made not in the presence of opposing counsel.

Arnold claims conception of the invention "on or about Nov. 1, 1912."

Langmuir's original preliminary statement alleged conception of the invention "all during the month of November, 1912," but when the office objected to that he filed a new statement alleging: "the first device embodying the invention set forth in the issue of the interference was conceived * * * between the middle of the month of July, 1912, and the first day of September, 1912." We will see that his attorneys claim for him conception of the invention in August, 1912, but he meant what he said—not conception of the invention but conception (unperceived) of a structure embodying the invention, but for which he perceived no practical use.

As early as 1884, Thomas A. Edison discovered that in an evacuated incandescent lamp the current did not all

go through the filament, but a portion leaked by jumping through the vacuum from one leg of the filament to the other leg. This was referred to as "Edison Current" and now is known as electronic discharge. In 1912, Langmuir was a recognized authority on incandescent lamps and was working in his laboratory on various tungsten lamp problems. In July, 1912, he asked an assistant, Sweetser, to do certain experimenting for him. It was known that Edison Current tended to improve the vacuum in a lamp by cleaning up the remaining traces of gas. Of his work between July 20 and September 13, 1912, Sweetser says:

* * * the primary interest in this experiment was the "clean up." The electron current was observed according to the general purpose of the experiment to determine its effect on the "clean up." As nearly as I can make out from the records, the purpose of the experiment is not to include a study of Edison current except as connected with the "clean up." (Langmuir Record on Motion, p. 734.)

During these operations some peculiar characteristics of the Edison current were observed and it is alleged by Langmuir's attorney that this was a reduction to practice of the invention, and the examiners-in-chief say it was a conception of the invention. It does not appear that what was done then was of any practical effect in the manufacture of incandescent lamps. The most that Langmuir can say in 1919 is:

(7) During August, 1912, we made experiments with lower gas pressures, using in many cases initial pressures of about 5 microns of nitrogen, and usually employing 200 to 250 volts on the anode. Under these conditions the residual nitrogen gradually disappeared, and in those cases in which the cathode temperature was rather high,

the final pressure obtained was of the order of 0.3 microns. Before this lowest pressure was obtained, the character of the discharge changed completely, and from the results recorded, and by comparison with experiments subsequently made (November and December, 1912), I can now recognize clearly that with this new type of discharge we actually had a device in which the current was limited by space-charge, substantially independently of positive ionization, at voltages as high as 250 volts. (Langmuir Record on Motion, p. 546.)

But the law examiner held the space charge effect to have been recognized in the prior art. So that by these experiments Langmuir was doing nothing new and adding nothing to the sum of human knowledge. He had neither conceived the invention nor reduced it to practice. It is easy to see why the peculiar words were chosen for use in his preliminary statement.

Langmuir's interest was still paramount in incandescent lamps and he continued looking at Edison Current from that aspect. In November, 1912, he proceeded to experiment with other lamps "exhausted in the regular way that tungsten lamps were exhausted." These lamps had a long filament with four separate leads dividing it into three loops. Sufficient current was applied to the middle loop to burn it out and experiments were performed with Edison Current between the remaining loops. Very elaborate notes are introduced with reference to all these experiments, but there is doubt as to why the middle filament was burnt out. The notes say to separate the other two; the testimony says for that purpose and also to effect "clean up" in the bulb. Probably the latter is true, as such a clean up was not new. Work with this bulb surprised Langmuir by showing some of the effects of pure electronic discharge. He testifies his purpose was

"to get an understanding of the fundamental laws involved, and thus *settle once for all whether or not* pure electron currents could be obtained in a practically perfect vacuum." This statement shows clearly that Langmuir had not made the invention before he started the November experiments. There is controversy as to what these experiments proved, but it seems clear that they produced nothing practical. Langmuir was still involved mentally with tungsten illuminating lamps and his report was to a group at the General Electric Laboratory which held weekly "conferences on matters relating to lamps" known as the Lamp Vacuum Committee. The minutes under date of November 21, 1912, show that Langmuir reported his results and then did not insist on a high vacuum, but thought his effect was produced by gas present. "A plausible hypothesis to account for some of these effects is that a small amount of some gas such as argon always remains in the lamp." He makes no suggestion of practical use of what he has discovered. He is merely an experimental scientist traveling the road the prior art considered by the law examiner had already traveled—of course unknown to Langmuir. He says that "after November, 1912, steps were immediately taken to develop applications of this pure electron discharge" (Langmuir Priority Record, p. 120), but the first date I find in the record is December 10, 1912, when Langmuir writes in his notebook what to him indicates that he has suggested to Coolidge that his experiments might have a practical bearing on X-ray tubes. The lower tribunals have rightly refused Langmuir any benefit of the work of Coolidge, because Coolidge was not called to testify. But even if benefit be given, the first date of thought of practical use is December 10, 1912, and Langmuir can have no date of conception prior to this, since the law

examiner has held that the invention lies not in laboratory experiments such as Langmuir had performed, but in commercial products. It was even later than this that he learned of DeForest's work with the audion. We need not go further with Langmuir's activities.

On October 30 and 31, 1912, DeForest brought one of his audions to the Western Electric Company and suggested its use as a telephone repeater. It was installed on an experimental telephone line and operated feebly for low sounds which produced small currents.

Prior to this time, Dr. Arnold had been employed by the Western Electric Company to work on telephone repeaters. He was recently from college where he had specialized in the physics relating to electric arcs between metal electrodes at various gas pressures. He had subsequently done graduate work along the same lines and as a part of this work had examined all available prior art literature. His entire life work was along the lines of electronic discharges. The DeForest audion was a device of this character and when the Western Electric people saw that it was not sufficiently useful for their purposes, they called in Arnold and on November 1, 1912, showed him the device in the experimental telephone line. Arnold testifies on pages 12 *et seq.* of Arnold's Priority Record, that on November 1, 1912, he explained that if the DeForest audion were further evacuated so that there would be in it only a pure electronic discharge not interfered with by ionization of the residual gas, the device would answer the purposes of the Western Electric Co. as a telephone repeater. This is confirmed by Colpitts and the other witnesses, they having been sufficiently informed of scientific facts to understand Arnold's suggestion. Arnold was thus able to make a practical or commercial application of the prior art laboratory knowl-

edge. I agree with the examiners-in-chief where they say:

According to this testimony, Arnold had a conception of a thermionic tube so thoroughly evacuated that it would have a pure electron discharge; and if it clearly appears that he knew how to produce such a tube, we would consider him entitled to November 1, 1912, for conception of the invention in issue.

Further, I am satisfied that Arnold knew how to produce such a tube. The law examiner says of the prior art "methods of attaining high vacua, sufficient to give a relatively pure electron discharge in a properly designed tube, were also known and available to persons skilled in the art." Arnold had worked in this specific art for years and it seems unreasonable to believe he did not know how to produce the vacuum. The testimony is that he did. We have seen that Langmuir relies on the four lead tubes as a reduction and they were "exhausted in the regular way that tungsten lamps were exhausted," which seems to indicate that a novel exhaust was not necessary.

Langmuir in his brief here says:

The important thing is to get a proper preparation of the tube and its parts; the method by which this is done is not important so far as the issues of this interference are concerned, so long as the result is achieved.

The Langmuir specification describes the device as prepared by evacuation, heat treatment of the glass tube, and heat treatment of the electrodes to eliminate occluded gases. (See also White's Answer to Q16, Langmuir Record on Motion, p. 601.) Arnold had developed an "arc repeater" filled with mercury vapor and had found that other vapors interfered with the work. He had therefore had to resort to heating the glass tube and heating the

electrodes to eliminate gases other than mercury. At his University laboratory he had been familiar with means for producing high vacua, but the laboratory of the Western Electric Co. had not such means. He looked about and could not find what he wanted in New York and finally ordered by cable from Germany the very vacuum pump recommended in Langmuir's specification. When it arrived he produced tubes which operated practically and the subsequent commercial operations of his company are admittedly reductions to practice. By means of Arnold's devices the first telephone message from New York to San Francisco was sent and the first trans-Atlantic wireless telephone operated.

After Arnold's disclosure on November 1, 1912, any one skilled, as he was, in the art could have produced the device of the issue. If I say a rubber button is a good thing to use in a hose supporter, I have conceived the button, even if I do not know how to make such a button. I may go to a rubber manufacturer and have him reduce my invention to practice and it will be my invention. So here, one skilled in the art could produce the device in issue as soon as told to do so by Arnold.

He who first conceives and gives expression to the idea of an invention in such clear and intelligent manner that a person skilled in the business could construct the thing, is entitled to a patent, provided he uses reasonable diligence in perfecting it. (McCormick Harvesting Machine Co. *v.* Minneapolis Harvester Works, 42 Fed. Rep., 152, 155.)

Here the law examiner has held that the prior art taught him to get the required vacuum.

Before the pump arrived Arnold studied the characteristics of DeForest's audions at voltages below those of

the issue and he found that one of these had a particularly effective high vacuum and it was successfully operated at voltages which are within the issue, but it is not necessary to hold it a reduction to practice as, in view of all the circumstances, the activities leading up to commercial use are sufficient to negative any lack of diligence on the part of Arnold.

Langmuir objects because Arnold did not proceed at once to use makeshifts to produce the proper vacuum in many bulbs, but I think he was justified in awaiting the arrival of the pump from Germany, especially since he studied the characteristics of what he had and started his associates preparing themselves for the work and did proceed soon after the arrival of the pump.

Adverse comment is made on Arnold's study of the De-Forest audion after he says he made the present invention, but that is just what Langmuir had White do in February, 1913 (Langmuir Record on Motion, p. 599, Q14).

The condition of the negotiations for patent licenses from Cooper Hewitt and from DeForest sufficiently account for the activities with the "arc repeater."

I have carefully examined the records and tried to weigh every point raised by the arguments or elaborate briefs, but it is impossible to state in an opinion every consideration going to fix a conclusion in the mind.

What I have said shows that Arnold was first to conceive and proceeded diligently to reduce the invention of all the counts, including 12 and 13, which call for a third electrode which Langmuir did not deal with until 1913.

The examiners-in-chief are reversed and priority awarded to Arnold.

KARL FENNING,
Assistant Commissioner.

October 27, 1923.

IN THE

COURT OF APPEALS

OF THE DISTRICT OF COLUMBIA.

IRVING LANGMUIR, *Appellant,* v. HAROLD D. ARNOLD.	No. 1680. Patent Appeal.

Opinion of the Court.

(Filed June 1, 1925)

(6 Fed. [2nd] 704)

(Before MARTIN, Chief Justice, and ROBB and VAN ORSDEL, Associate Justices)

Appeal from a decision of an Assistant Commissioner of Patents in an interference proceeding awarding priority to the junior party, Arnold, and reversing concurrent decisions of the Examiner of Interferences and the Board of Examiners-in-Chief.

The invention is a thermionic tube adapted to be used as a relay in long distance telephone systems, as a detector or amplifier in wireless systems, or as a rectifier of alternating currents. The issue is expressed in thirteen counts, of which the 1st, 7th and 13th, here reproduced, will serve as examples:

"1. A high vacuum electron discharge device comprising an envelope, an incandescent cathode

and an anode, the space in said envelope being evacuated to such degree that the passage of current produces no appreciable positive ionization when the impressed voltage is as high as 200 volts."

"7. A discharge device comprising a tube and electrodes therein one of which is adapted to emit electrons, the degree of evacuation and the relation of the parts of the device being such that the device is capable of being so operated, when voltages materially higher than ionization voltages are impressed on electrodes of the device and when the electron emission has any value such that the space current is below the saturation region at such voltage, that the line obtained by plotting the logarithms of any values of said current below the saturation region as ordinates against the logarithms of the corresponding values of said impressed voltages as abscissae is straight and continuous."

"13. The method of controlling an electric current in one circuit by an electromotive force in another circuit which consists in causing said current at voltages materially above ionization voltages to pass as a discharge across a vacuous space between an electron emitting cathode and an anode, maintaining a high vacuum in said space, governing or limiting the current by a space charge effect in said space substantially unaffected by positive ionization, and superimposing the effect of said electromotive force on said space charge effect to control said current in a stable and reproducible manner."

The attitude of the junior party, appellee here, when this interference was declared, is significant. He filed a motion challenging the patentability of the issue and sought and obtained permission to take evidence in sup-

port of that motion. The result was the taking of voluminous testimony by the parties on this issue, which by stipulation is in the record here. The Law Examiner, to whom this question was initially referred, sustained the patentability of the issue and his decision is controlling here. We therefore start our inquiry in this appeal with the established fact that, so far as this proceeding is concerned, the issue is patentable; in other words, that something more than mere mechanical skill was involved in the result achieved.

The examiner of Interferences, in an exhaustive opinion, awarded priority to the senior party, Langmuir. The Board, on appeal, directed attention to the fact that, structurally considered, the tubes of both parties outwardly are substantially identical with the Fleming valve and the DeForest audion of the prior art; that the invention has been referred to as a "thing compact of glass and metal". The Board then pointed out that this definition, although correct as far as it goes, is inadequate because it applies equally well to the prior art devices, and that to this definition should be added the qualification that the device "operates with a *pure* electronic discharge above the voltage of positive ionization and below saturation", and proceeded: "But how is one to know whether the discharge is purely electronic? In other words, how is one to know whether a tube embodies merely the prior art devices or the invention of the issue? * * * For example, count 1 specifies that the envelope of the tube is evacuated to such a degree that the passage of current produces no appreciable positive ionization when the impressed voltage is as high as 200 volts. Thus the count distinguishes from the prior art, not by features of structure, but by a characteristic which is manifest

while the device is operating at or above a certain voltage."

Later in its decision the Board suggested that the question to be determined was, who of the parties "first knowingly and understandingly conceived and produced such a tube"; that Arnold, the junior party, did not claim to have conceived the invention prior to November 1, 1912, or to have reduced it to practice prior to the 29th of that month; that Langmuir, on the other hand, alleged conception, disclosure, sketches, written description and successful operation prior to September 1, 1912, followed in November of that year by the successful operation of other devices embodying the invention. The Board then carefully reviewed the testimony in support of Langmuir's contentions and found that he had conceived the invention of counts 1 to 11, inclusive, as early as September 1, 1912, and had reduced the same to practice by November 19th of the same year; that, as to counts 12 and 13, Langmuir had conceived prior to April 8, 1913, and had reduced to practice by April 15th of that year; that Arnold conceived and reduced to practice the invention of all of the counts except counts 1 and 11 on April 25, 1913, and that counts 1 and 11 were not reduced to practice until after Langmuir's filing date.

The attitude of the Assistant Commissioner toward the case was that of the junior party upon the declaration of the interference, namely, that the patentability of the issue was doubtful. He says: "The line between the prior art and the issue is attenuated and if there is patentability, it must be as set out in the decision of the Law Examiner on the motion, and I do not understand either party to attack that decision here. Arnold alleges that when he made the invention, he thought he was following

the prior art and not producing something patentable, and an undercurrent of that attitude seems to tinge his whole case. This is why he filed so late." Proceeding from that prostulate, the Assistant Commissioner has accepted as controlling on the question of conception and reduction to practice, on behalf of Arnold, testimony of a vague and general character and which failed to satisfy the lower tribunals, as it also has failed to satisfy us. The decisions of those tribunals are so clear and satisfying that we are content to rest our opinion upon the reasoning there given.

It results that the decision is reversed and priority awarded Langmuir.

Reversed.

CHAS. H. ROBB,
Associate Justice.

IN THE

DISTRICT COURT OF THE UNITED STATES

FOR THE DISTRICT OF DELAWARE.

GENERAL ELECTRIC COMPANY,
Plaintiff,

v.

DEFOREST RADIO COMPANY,
Defendant.

Nos. 589 and 598
In Equity.

The Opinion of Judge Morris.*

(23 Fed. [2nd] 698)

These two suits of General Electric Company against DeForest Radio Company were tried together. In the first suit all the claims of patent No. 1,558,436, granted to Irving Langmuir, assignor to the plaintiff, October 20, 1925, for "electrical discharge apparatus and process of preparing and using the same" upon an application filed October 16, 1913, and renewed March 14, 1916, are in issue. It is known as the high vacuum tube patent. Infringement is conceded if the claims are valid. Validity is denied for want of invention and novelty and because of prior knowledge and use, for double patenting and upon the ground that Harold D. Arnold, not Langmuir, was the first inventor.

The specification, claims and testimony are so interwoven with scientific theories, more or less abstruse, that

*The opinion of Judge Morris dealt with four Langmuir patents. We are here concerned only with Langmuir patent No. 1,558,436. We have, therefore, only printed that portion of the opinion dealing with this patent.

it is somewhat difficult to isolate and keep separate from the principles of physics involved Langmuir's conception and idea of means. Yet an analysis of the Langmuir device and its elements discloses that, apart from its functioning and results it is nothing more nor less than a Fleming valve or DeForest audion, for example, in which a higher vacuum, maintainable during operation, exists. How much higher the vacuum must be to bring the tube within the patent is not definitely fixed in terms of pressure. The specification states merely that "the evacuation of the device should be preferably carried to a pressure as low as a few hundredths of a micron, or even lower, but no definite limits can be assigned." A micron is a pressure equal to a millionth of a meter or a thousandth of a millimeter of mercury. It corresponds to a barometer reading of that value. The normal barometer reading in the open air is about 760 millimeters. The justification for the failure to assign definite pressure limits is that the invention "comprises devices in which the electrical current is carried by negative charges called electrons, emanating from the cathode, independently of gaseous ionization"—a device in which the residual gases play no part in the operation. The results desired to be obtained are stability and reproducibility of operation and increase of power. The production of these results by the specified manner of functioning is dependent not on the degree of vacuum alone, but upon four coordinating variables—geometry or relation of parts of the tube, temperature of cathode, voltage of anode and degree of vaccum. This fact makes it apparently unavoidable that the claims be functional in form. But they must, of course, be construed to cover the thing. Walker on Patents §163. Claim 26 is comparatively simple. It is:

"A discharge device comprising a sealed off envelope and electrodes therein, the envelope being shaped and the electrodes located so that the energy of the discharge is delivered mainly upon one or more of the electrodes, the inner wall of the envelope and electrodes being so free from occluded gas and the pressure in the tube being sufficiently low, with respect to the spacing of the electrodes and the energy of the discharge, so that the device is capable of passing a sustained discharge of one tenth of a milliampere at forty volts, without developing any substantial positive ionization effects."

The Fleming and DeForest tubes are "discharge devices comprising a sealed off envelope and electrodes therein, the envelope being shaped and the electrodes located so that the energy of the discharge is delivered mainly upon one or more of the electrodes." The next clause of the claim—"the inner wall of the envelope and electrodes being so free from occluded gas and the pressure in the tube being sufficiently low, with respect to the spacing of the electrodes and the energy of the discharge"—has to do with the manner and degree of evacuation. Underlying this clause are these facts: The glass wall and the electrodes harbour large volumes of occluded gases. Heat is necessary to expel these gases so they may be removed by the pump. If not removed before the tube is sealed off the heat occurring during the operation of the tube expels them, destroying in large degree the vacuum. "The spacing of the electrodes"—one illustration of the geometry of the tube—is a factor because the permissible gas pressure in the tube increases with the proximity of the electrodes to each other. This varying relation is due to the fact that the opportunity for the electrons to collide with gas molecules varies with the length of the path the electrons have to travel. "The energy of the discharge"

may be interpreted in terms of power which is the product of the current values and the voltage. The unit of current flow is the ampere or the current which flows at a pressure of one volt through a closed circuit having a resistance of one ohm. The power of a circuit having a pressure of one volt and a current of one ampere is one watt. The power output of the device of claim 26 is .004 of a watt or 4 milliwatts. And increase of energy means an increase in the number and velocity of the electrons passing from cathode to anode and consequently an increase in the number and effect of collisions of electrons with gas molecules. It follows, of course, that if the maximum voltage at which a given tube will function without ionization is increased ionization will occur and the tube fail to function in the manner specified in the patent. "Ionization," by which is meant the conversion of atoms or molecules into ions, is explained by the "Electron Theory." By this all atoms known to chemistry are deemed to be made up of a nucleus endowed with a permanent positive electrical charge around which one or more electrons, each of which has mass or weight and carries, or is, a natural unit of electricity, revolve at inconceivably great speeds in regular orbits in somewhat the same manner as that in which the planets of our solar system revolve about the sun. According to this hypothesis the chief difference between the chemical atoms lies in the number and arrangement of their electrons. Under normal conditions the electrons are maintained within their atoms and in their orbits by the attractive force of the positive nucleus which, electrically, exactly balances and neutralizes the negative charge of the electrons of the atom. Consequently every atom having its normal complement of electrons exhibits no electrical effects. If, however, by impact, or otherwise, an atom loses an electron and becomes

an ion it is thrown out of electrical balance. The positively charged nucleus predominates and exhibits a unit positive charge. In thermionic tubes ions are created by the impact upon the gas atoms or molecules of some of the myriads of electrons constituting the current flowing from the hot cathode to the cold anode—the Edison Effect. See Westinghouse Elec. & Mfg. Co. *v.* DeForest Radio Tel. & Tel. Co., 21 Fed. (2d) 918. To dislodge an electron from its atom the colliding electron must have sufficient momentum. The velocity required for this momentum is given to the electrons mainly by the pull or attractive force of the positively charged anode. The strength of the pull increases, other conditions being stable, with the anode voltage. For the gases with which we are here concerned 15 to 25 or 30 volts constitute the ionizing voltages.

When substantial numbers of atoms or molecules are being converted into positive ions by the electron stream the "ionization effects" forbidden by claim 26 occur. One effect of ionization is an increase in the current across the tube over the value it would have at the same voltage in the particular tube were the vacuum sufficiently high to prevent ionization. Such increase is due to two facts. First, the electrons, being negative charges of electricity, tend in the absence of a countervailing force, violently to repel one another and thus to diminish the number, and so, the value of the current, passing to the anode. Positive ions in the field constitute a countervailing force and consequently expedite the flow of the electrons to the anode. Second, the positively charged ions are drawn with great force to the cathode, the negative electrode, bombard it and thus increase its temperature. As the electron emissivity of the cathode increases with its temperature the ion bombardment of the cathode serves to

increase the supply of electrons and consequently the current passing to the anode. This bombardment is so severe that, if continued, it destroys the filamentary cathode. Another effect to which substantial ionization usually gives rise is a blue glow in the tube. This, as I understand it, is accounted for upon the hypothesis that as the electrons are shifted in the atom, by impact of the electrons, from one orbit to another at prodigious speeds they produce waves or vibrations in the ether which constitute light. The ultimate effect or result of ionization is an unstable, non-reproducible and, in a measure, non-controllable current. As it is necessary, in order to prevent the destruction of the cathode and obtain a stable current, to operate gassy tubes below ionization, their power output—the product of current and voltage—was limited. These constitute obvious defects.

These defects are not present in the tube of the patent. It operates without substantial ionization. When there is no substantial ionization the current increases and decreases in a fixed relation to the voltage of the anode unless and until the anode voltage is made sufficiently high to draw to the anode all the electrons emitted at the cathode. The electronic emissivity of a given cathode increases with its temperature. This fact is known as "Richardson's Law." When a voltage high enough to carry across the tube all the electrons emitted is reached a further increase of voltage, which has no power to increase the supply of electrons of which the current consists beyond the limit of emissivity imposed by the temperature of the cathode, produces, of course, substantially no change in current. The current that is thus substantially independent of the voltage is known as the saturation current. Operation of the tube above and below this critical voltage is spoken of as in the saturation region

and below saturation respectively. If a tube is operating below saturation an increase of the electron supply by an increase of cathode temperature, but with no increase in voltage, produces no marked change in the current. Decreasing the electrons emitted by the cathode by decreasing the cathode temperature is likewise without effect upon the current, provided, of course, that the decrease in the supply of electrons is limited to the electrons emitted in excess of those pulled across the tube by the given voltage. The fact that if the anode voltage remains stable the current can not be increased by an increase of the cathode temperature, beyond that required to supply the electrons capable of being pulled across the tube at the given voltage is illustrated by the "flat top temperature curve" on the following graph.

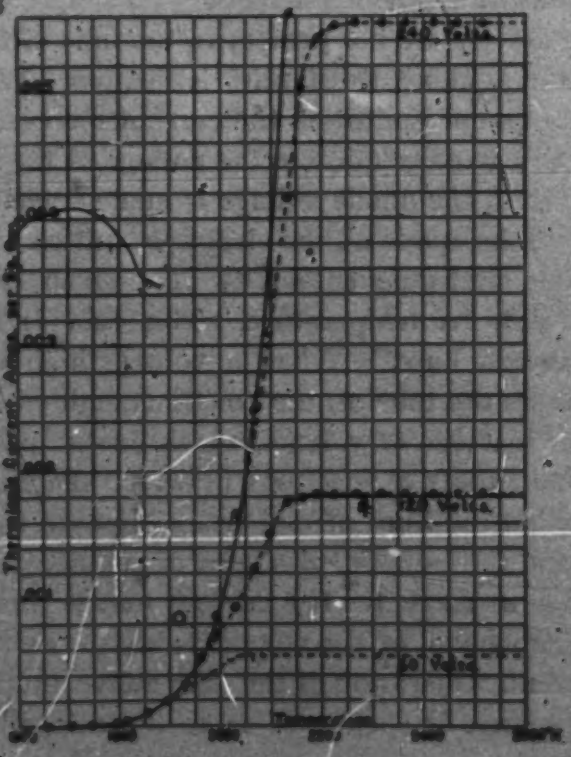
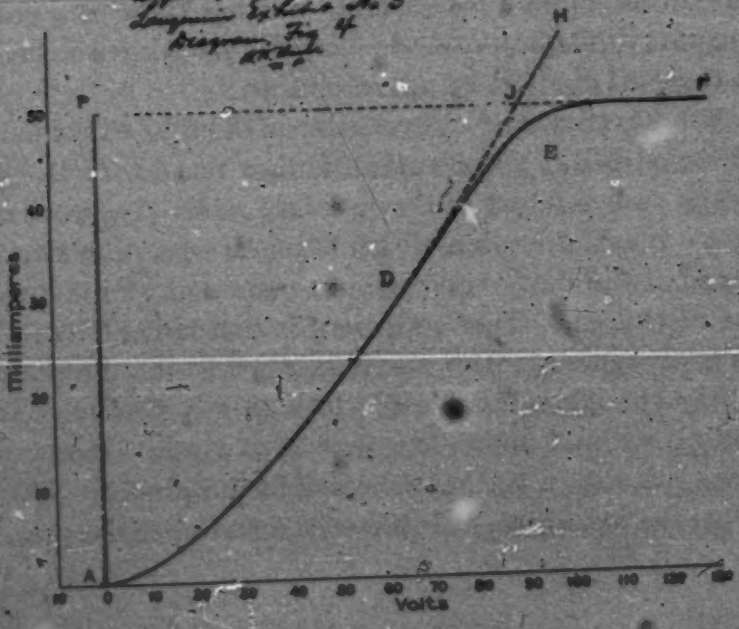


Fig. 1.

The reason that the current does not increase beyond a certain point dependent upon anode voltage with the increase of the temperature of the cathode is that the electrons, all being negatively charged, exert powerful repelling forces on one another. When this force of repulsion equalizes the pull or effect of the voltage on the anode, the anode is without power to draw to itself a greater number of electrons. The current-limiting effect of the electric field of the electrons on one another is known as the "space charge effect." It is space charge which produces the flat top of the temperature emission curve in the foregoing graph.

When the temperature of a cathode is fixed and constant and the voltage is increased the limitation upon the electrons limits the current. This is illustrated by the following graph whereby it appears that the last few increases in voltage make no increase in current—there being no more electrons to draw across the tube.



The curve of this graph, which when plotted on logarithmic paper appears, up to the point approaching saturation, as a straight line, disclosed a relation existing between current and voltage. That relation is expressed in the specification thus:

> "In most devices of simple construction which embody my invention, the discharge current passing through a given space with the cathode at a sufficiently high temperature with respect to the voltages employed, varies directly with the 3/2 power [square root of the cube] of the impressed voltages."

"A" to "D" of the curve on the current-voltage chart, in which the temperature is constant, is the space charge part or that in which the current is limited by anode voltage and follows the 3/2 power law. The flat top represents the saturation part or that in which the current is limited by the cathode and its temperature. The converse is true in the first or current-temperature chart in which the voltage is constant. In that the rising part is the part limited by cathode temperature while the flat top is the part limited by space charge.

Another characteristic peculiar to the tube of the patent, as stated in the specification, is that the device is "practically independent of the pressure when the pressure is below a certain value which depends upon the size and shape of the device and upon the current and voltage of the discharge." That statement is undoubtedly true if it be interpreted to mean that if in a given tube the pressure is low enough to enable the tube to function at a given voltage without ionization, that is, as a pure electron discharge device, a further decrease in the pressure will not affect the discharge. It is likewise true that if the pressure

is less than that required for a given voltage in a given tube it may be increased up to the pressure immediately below that at which substantial ionization would occur at the given voltage without affecting the discharge. The discharge, however, is in no sense independent of the pressure if the maximum voltage at which a given tube will function without ionization is increased, for ionization would instantly occur and the tube fail to function in the manner specified in the patent. In such instance a decrease in pressure simultaneously with the increase in voltage would be necessary to avoid ionization. In its simplest aspect this is due, of course, to the fact that if ionization is to be avoided above ionization voltages collisions must be avoided between electrons and gas molecules and that the number of collisions in a given tube, dependent upon the relative density of the two, is increased, the pressure being stable, by an increase in the number of electrons pulled to the anode by the increased voltage.

These scientific explanations, arising mainly out of the electron theory, of the functioning of the high vacuum tube change not at all the fact that it differs structurally from the Fleming valve and DeForest audion only in the degree of vacuum maintainable during operation. This was expressly conceded during the pendency of the application in the Patent Office. The fundamental questions here in issue are not changed and their solutions are, I think, but little affected by the theories by which the functioning of the high vacuum tube is accounted for. If it was not known to those skilled in the art how to produce, in a Fleming or DeForest structure, for example, a vacuum sufficiently high to enable the tube to function above ionization voltages without substantial ionization

and Langmuir solved the problem and made the necessary disclosure of its solution in his patent, manifestly he would be entitled to a patent for his disclosed method and device as a reward quite apart from his knowledge or lack of it with respect to scientific principles or laws of physics explaining the functioning brought about by the high vacuum. Moreover, independently of whether or not invention was necessary to create a vacuum of the required degree, Langmuir would be entitled, I take it, to a patent for his device regardless of his ability or inability to explain its functioning in principles of physics, if he was the first to appreciate that a high vacuum maintainable during operation in a Fleming or DeForest structure, for example, would constitute means whereby the results produced by the high vacuum tube could be accomplished, provided, of course, he reduced to practice with reasonable diligence the device of his mind.

Upon the question whether the claims for the process of making the high vacuum tube or those for the tube itself, which because of its stability, reproducibility and power has made possible radio broadcasting, modern radio reception and long distance telephony, involve novelty and invention the parties differ widely. The plaintiff asserts, with apparent confidence, that the patent is for invention of a high order—equal to or greater than that of DeForest for the three electrode tube. The defendant, with equal confidence, finds not only all that Langmuir did but all that he discloses with respect to the principles in accordance with which the device functions spread upon the records of the prior art. Since the Fleming valve and the DeForest audion were old and the structure of the tube of the patent differs from these only in the degree of vacuum maintainable during opera-

tion, the first crucial question is whether claims 30, 31 and 32, directed to the process of making tubes having a vacuum of the required degree are valid. Claim 31 is:

> "In the process of producing a hot cathode discharge device, treating the interior surface of the envelope and the operating parts to liberate therefrom occluded gas, and removing from the envelope gas liberated by said treatment and free gas originally contained therein, continuing these operations until the occluded and original free gas is so thoroughly removed as to enable the finished sealed-off device to operate below saturation in a stable and reproducible manner at a voltage above fifty volts and with a current greater than one milliampere and with the energy of the discharge delivered mainly at one or more anodes."

To find wherein, if at all, this and the other process claims go beyond the discoveries and ideas of others, beyond the use of wise judgment in selecting and combining those discoveries and ideas, or beyond mechanical skill in applying them to practical results, the specification and the prior art must be examined. The specification states:

> "For the evacuation of the device the glass walls of the tube are carefully heated to as high a temperature as the glass will stand without softening and in general the most approved methods of incandescent lamp exhaust are used. The evacuation of the tube preferably while still heated is carried out by means of a suitable evacuating means, for example, a Gaede molecular pump, which removes vapors as well as gases. Chemical evacuating means such as electrically vaporized calcium or magnesium may also be used. Either before or during the evacuation the anodes may be heated, especially when the anodes are to be run at ele-

vated temperature during the normal operation of the device. In this case the temperature is preferably carried close to brilliant incandescence. In the case of the structure shown in Fig. 1, the heating may take place by passing an electrical current through the wire 12. The heating, especially of solid anodes such as shown in Figure 2, may take place in a suitable vacuum furnace, the temperature preferably being raised to 2,500° C. or even higher. Bombardment is a very effective means of removing occluded gas from anodes."

The steps and precautions requisite to successfully evacuate by bombardment are then described after which the specification adds:

"After the metal has been freed from occluded gas reabsorption of gas will not readily take place even though it is exposed to the air or other gases. For example, anodes thus treated may be removed to other apparatus which then may be evacuated with less electron bombardment of the anode or anodes. * * * It is also true that when the anode has been carefully freed from gas residual free gas, even if present in a sufficient amount to cause some gas ionization when the apparatus is first started, does little harm, as it is quickly removed by the gas clean-up effect when the device is operated."

The prior art, however, as I understand it, discloses that long before the earliest date claimed for Langmuir it was known not only that large quantities of gas are occluded in the glass walls and electrodes of an electrical-discharge device and that unless removed before or during evacuation the gas will be driven out by the heat of operation and thus detrimentally increase the pressure of the vacuum, but also that the occluded gases could be re-

moved and the vacuum created and maintained by the very steps prescribed by Langmuir for removing the occluded and free gases of his device. In May, 1896, the "American Electrician" published an article by Thomas Duncan in which he said:

> "If an incandescent lamp be exhausted until no air can be seen escaping through the valves of the pump, and the filament then incandesced, considerable quantities of air will be expelled at each operation of the pump, thereby showing that this air has been occluded in the pores of the carbon filament, and could not have been gotten rid of without heating the filament and driving the air out into the vacuous space surrounding it.
>
> "This heating also assists in drawing off the air which clings or adheres against the glass upon the inside of the bulb. If the electrodes are made from aluminum or other porous metal, the secondary terminals from a spark coil can be applied to them, and set in operation in a similar manner to that in which the tube is to be used afterwards. This can not help but be a ready and satisfactory means of eliminating the air occluded within the electrodes."

A résumé of Incandescent Electric Lamp Exhausting by S. E. Doane, published in the "Electrical World and Engineer" of May 21, 1904, says:

> "The exhausting of incandescent electric lamps has developed into a highly specialized branch of the lamp manufacture. * * * The completed lamp must not only be free from gases and vapors, but must also have had those parts capable of giving off gases and vapors, thoroughly freed from them. The only way we knew to accomplish this was to highly heat everything we wished to free

from gas. We had three things to heat: the glass, the filaments and the joints between filaments and leading-in wires.

"The glass was heated by an asbestos cone-shaped hood painted black on the inside. The heat from the lighted lamp furnished all the heat necessary. The lamps could be heated hot enough to cause the bulb to collapse if the hoods were made too thick. The filaments were also heated sufficiently by the current, * * *."

Dwyer, in his patent No. 596,694, granted January 4, 1898, for a process of producing high vacuums in incandescent electric lamps or similar receptacles during their manufacture, recites that in the past such lamps have been exhausted by mechanical pumps, "by chemical processes involving the displacement or absorption of the gases contained in the lamp, or by combinations of these processes." He says that a partial vacuum is readily obtained by a good mechanical or mercurial pump but that complete exhaustion by this means alone is not possible. He then adds:

"To carry the vacuum still higher, it has been a common practice to heat the lamp-bulb by either an external source of heat, such as a gas-flame, or by an electric current passed through the lamp-filament, or by both of these means combined, so as to expand the gases in the lamp, and also to drive off from the lamp-filament itself and its supports, more particularly the joint between the leading-in wires and the filament, which joint is usually made of some form of hydrocarbon paste, gases occluded therein, while continuing the pumping operation."

Soddy, in his patent No. 859,021 of July 2, 1907, for the employment of certain reagents in the process of producing high vacuum, declares:

"In the production of high vacua not only has the air to be removed but also the gases occluded or condensed on the walls of the vessel being exhausted and on the contained electrodes or filaments or other contents of the said vessel, which condensed gases are given up slowly after exhaustion and if not removed during the exhaustion cause the vacuum to deteriorate. * * *

"The heating and expelling of the condensed and occluded gases may be effected in any usual, or suitable, manner of expelling condensed and occluded gases from the walls and contents of vessels being exhausted. The usual manner of effecting such an operation is to heat the vessel while it and its contents are subjected to the same treatment as they are subjected to in after use. In incandescent electric lamps for example an electric current is passed through the filament, and in X-ray bulbs an electric discharge is passed between the electrodes during the continuation of the exhaustion."

Many other references disclose the baking of the walls of the envelope of a discharge device, the heating of the electrodes, incandescing the filament and electron bombardment of metallic electrodes to expel occluded gases. The gas clean-up effect was likewise old at the time Langmuir began his operations. One instance of its disclosure is in patent to Thatcher No. 1,028,636, granted June 4, 1912, application for which was filed March 30, 1910, for method of exhausting vessels, in which it is said in part:

"I institute the intensive incandescence of the filament proper, that is, I bring the current voltage up to a sufficient intensity to produce the blue haze phenomenon, and maintain the same until the blue haze disappears and the desired almost perfect vacuum is attained. * * *"

Dr. E. Leon Chaffee testified (R. Vol. 1, p. 159):

> "It has long been known that the existence of this blue glow improves the vacuum, probably by bombarding the walls with gas ions and consequently causing them to stick to the glass walls. * * *"

These steps of the prior art are the identical steps disclosed by Langmuir. Nor are his disclosures with respect to how these steps are to be employed any more ample or complete with the possible exception of heating by bombardment. But bombardment has no saving power for the claims are not restricted to heating by bombardment. They are broad enough to include any method of "treating the interior surface of the envelope and the operating parts to liberate therefrom occluded gas, and removing from the envelope gas liberated by said treatment and free gas originally contained therein." The plaintiff, however, places some reliance upon the clause in the claims directing continuance of the steps until the desired vacuum is attained and cites Badische *v.* Kalle, 104 Fed. 802. But in that case those skilled in the art were of the opinion that a more prolonged or intense application of the old steps would not accomplish the desired result. Such is not the evidence here as I understand it. Moreover, the tools of the evacuating art were constantly improving. In the early days of the incandescent lamp art manufacturers used the Sprengle pump to obtain their vacua. It gave way to the Geissler pump which, in its turn was superseded or supplemented by chemical evacuating processes. It is, I think, not denied that these old pumps and at least some of the chemical processes left in the tube mercury or other vapors having a pressure too high for the tube of the patent. But if Langmuir makes in his specification any disclosure of

steps or means to avoid that result it is by the use of the new, improved Gaede molecular pump. That pump is highly efficient and, when properly used, leaves no free gas or vapor that will prevent the functioning of a thermionic tube above ionization voltages without substantial ionization. But Langmuir is entitled to no credit for that. I think the process claims are invalid.

This conclusion carries with it as a necessary corollary that the device itself, apart from its functioning and use, is lacking in patentable novelty. The inventive quality of the device claims, if any they have, must consequently reside in the discovery of a new principle that thermionic discharges above ionization voltages can be produced without substantial ionization if the vacuum be sufficiently high and the disclosure that the device of the claims constitutes suitable means for putting the principle into practice to obtain useful results, or, in the application of that principle, if known, to a useful purpose—in the realization that the instability, non-reproducibility and lower power output of the gassby tube was due to inadequate vacuum and the conception of a tube with a higher vacuum as a means whereby stability, reproducibility and high power output in thermionic devices might be had. That Langmuir was not the first to discover that a pure electron discharge, a discharge without substantial ionization, can be produced in a thermionic device if the vacuum is sufficiently high was indicated by Richardson's Law, evolved and formulated about 1903. If, perchance, that law was not universally accepted by physicists as being operative in high vacua, as was suggested by Soddy, Pring, Parker and some others, the publications of Lilienfeld in 1910 were clear, complete and specific upon this point. In fact, Langmuir admits (I. R. p. 1378) that Lilien-

feld had thermionic discharges above ionization voltages "substantially free from the effects of positive ionization." Moreover, if a thermionic discharge is unaccompanied by substantial ionization all the asserted "earmarks" or characteristics of plaintiff's device are present for they are but incidents flowing from a sufficiently high vacuum for the voltages employed, or, otherwise expressed, from an absence of ionization. These characteristics are, or include, (1) regularity and reproducibility of operation, (2) 3/2 power relation of current to voltage, (3) no blue glow or other visible evidence of discharge, (4) cathode not heated by the discharge, (5) current limited by space-charge effect and (6) discharge independent of pressure in vacuum below certain pressure in the sense hereinbefore stated. As I understand the evidence these "earmarks" are likewise characteristics of the Fleming valve and original DeForest audion when operated at non-ionizing voltages. It thus seems obvious that the merit of the invention, if any, must lie in the realization that the known pure electron discharge to be had in a high vacuum would overcome the special difficulties and limitations of thermionic discharge devices. Whether this realization and the increase of vacuum in structures of the Fleming and DeForest type was a probable natural development of the art or one requiring inventive skill is, like the question of the presence or absence of invention in other cases, not without some difficulty.

One class of evidence which often carries much weight is the necessity for a series of experiments before the result can be arrived at. Such evidence raises a strong inference that the result was not obvious and constitutes a real addition to public knowledge. But for such experiments to be of much value the patentee must have started

his experiments with knowledge of the state of the art or his experiments may have succeeded in enabling him to redisclose only what was already known. Langmuir made many experiments over a long period of time. Those that were first made were, however, for the purpose of discovering abstract principles and not for the purpose of arriving at practical results. He made discoveries but he did not immediately, or for some time, perceive that they had any practical use. Moreover, the discoveries to which his experiments led him, so far as we are here concerned, were those already made by Lilienfeld and others. Great credit, bearing upon the issue of invention, is claimed by the plaintiff for Langmuir for discovering from his experiments that electrons will boil out of a hot cathode in a high vacuum, that in a high vacuum the current varies with the 3/2 power of the voltage and other characteristics or incidents of a discharge in a high vacuum without substantial ionization. But disclosures of the prior art reveal that Langmuir, great and renowned physicist that he is justly conceded to be, was, in this instance, travelling all unknown to him, over a field already well explored. Fleming, the inventor of the Fleming valve, published in the "Scientific American Supplement" for January 20, 1906, an article on the electric conductivity of a vacuum, disclosing not only that electrons are emitted by a hot cathode in a high vacuum but also "that a high vacuum may be a very good conductor, provided that the negative electrode is rendered incandescent. This shows that the obstruction which a high vacuum offers to the passage of electricity is not due to the mere reduction of the matter in the space (that is, to the rarefaction of the gas), but is, in some way or other, largely dependent upon the temperature of the electrodes; the resistance

to the passage of electricity through a vacuum can be rendered very small by intensely heating the negative electrode," thus revealing that a current could be had passing from cathode to anode. In addition, Fleming stated: "If we take measurements of the current passing through the vacuum when the negative electrode is an incandescent carbon filament and the other a cold metal plate, and, at the same time, measure the difference of potential between the electrodes, we find that the conductivity, as measured by the ratio of current to voltage, is not constant, but varies with the electromotive force." Furthermore, that Fleming knew the difference between a high and low vacuum is made manifest by his statement: "The vacuum is said to be low when the original normal air pressure in it is reduced to one-thousandth atmosphere, or it may be only to one three-hundredth. It is said to be high when it is reduced to one hundred-millionth of an atmosphere." It is true, as shown by the Fleming curve sheet, that Fleming did not employ in his valve a high vacuum but it is also true that Langmuir, Q212, conceded "There is no advantage in the device of the character of the Fleming valve to go to pressures of less than 50 microns." Both C. D. Child, in an article in the "Physical Review," Vol. 32 (1911), and Lilienfeld, in an article entitled "Conduction of Electricity in Extreme Vacuum," published in "Annalen der Physik," Vol. 32 (1910), disclosed that with the aid of certain simplifying assumptions, such as the ignoring of the initial velocity with which the electrons are boiled out of the cathode, the discharge current varies in accordance with the three-half power of the voltage. This is conclusive evidence, as I understand it, that in a high vacuum the current is under control, stable and reproducible and, since high voltages

were employed, that high power levels may be attained by the employment of a high vacuum. "Space charge effect" was, likewise, but a rediscovery. This is made certain by an article by Lilienfeld in "Physikalische Zeitschrift" 1908 in reply to an article by Soddy dealing with the Wehnelt cathode in high vacuum in which Lilienfeld said:—

> "* * * it is not exclusively the electrons emitted from the exide cathode which, as was often assumed, determined the discharge in high vacua, but that the discharge depends essentially on a second factor. I pointed out more specifically in my second paper this view, that in consequence of the absence of the last traces of gas the number (volume density) of the negative electrons supplying the current becomes great in comparison with the number of gas molecules per unit volume, so that therefore the tendency exists for the formation of the greatest possible negative space charge—which opposes the current transport by the negative electrons.
>
> "The higher the vacuum, the greater the current density, the more prominent this new kind of discharge becomes * * *."

That the discharge in high vacuum devices is practically independent of the pressure when the pressure is below a certain value was discovered by Langmuir after Lilienfeld had made the disclosure in his article of 1910, where he said:

> "* * * from a certain maximum value of the gas density downwards the number of positive charges formed per negative charge, *i. e.*, per negative electron is independent of the gas density.
>
> "Since we usually regard positive charges as originating from molecules (or atoms) we can put

this result in the following form: the number of positive charges per molecule increases continually with diminishing gas density in the region of validity of the function K which is independent of the gas density provided other conditions (the potential gradient) are kept constant."

In view of these publications it seems to me that the only permissible inference to be drawn from Langmuir's experiments is not that they constitute evidence of invention but is rather that Langmuir was not abreast of the developments in this particular art when he made his experiments.

Other evidence bearing upon the issue of invention is the great utility of the high vacuum tube. But in 1912 the radio art was young. Fleming did not need for his purposes, as Langmuir testified, a higher vacuum than that employed by him. The DeForest audion was not in wide use. Langmuir did not see one until 1913. Under such circumstances it would be difficult to say that the high vacuum tube satisfied a long-felt want or produced results long sought or that the evidence of utility is here indicative of anything more than a proper natural development of the art. Moreover, the fact that falls but little short of a demonstration that the employment of the known pure electron discharge above ionization voltages in tubes of the DeForest type was but the availment of those skilled in the art of the store of knowledge that had been accumulated and lay ready at hand is that when Arnold, who had had long experience with electrical discharges in high vacuum, was shown a DeForest audion for the first time on November 1, 1912, and saw it in operation he immediately realized and said, in effect, that by increasing the vacuum the discharge would be sufficiently stable and at adequate power levels to enable the

tube to be employed as a relay device in transcontinental telephony. While not unmindful that invention may sometimes be the result of an instantaneous happy thought, yet the state of the art is strongly confirmative of Arnold's own view at the time that the improvement suggested by him was obvious to one skilled in the art. The act of Arnold turns the scale so overwhelmingly that it lies athwart a finding of invention.

The patent is likewise invalid, in my opinion, because of prior knowledge and use by DeForest. The specification states: "Ordinarily the gas ionization in the audion begins to be important somewhere between 20 and 30 volts." That, as I understand it, means that at this voltage the current becomes affected by positive ionization and the tube ceases to function as a pure electron discharge device. Yet, prior to August, 1912, the Federal Telegraph Company of California, by which DeForest was then employed, used a B battery of 36 cells, another of 45 cells, or 54 and 67½ volts respectively, with the audion. When used as an amplifier the amplification increases with the voltage. The testimony of Langmuir, XQs761-767, as I understand it, makes it clear that this voltage was employed for amplifying purposes and so with a discharge current substantially unaffected by ionization. That DeForest, though not skilled in the art of evacuating his device, knew the effect thereon of an increased vacuum, though he was very probably unaware of the extent to which it could be carried, is disclosed by his letters of July 26, 1912, and August 14, 1912, to the McCandless Company, the manufacturer of audions for the Federal Telegraph Company. The first letter is:

> "Out of the last lot of 24 audion bulbs which you manufactured for us there are only 4 that came

up to proper sensitiveness test. Apparently the vacuum in the other bulbs is too low, because in these latter bulbs we notice that the blue arc or cathode beam starts suddenly at 15 or 20 volts, under which condition the bulb is not sensitive."

The other letter reads:

"We took two of the poorest of the discarded 20 to a San Francisco glass-blower, unknown to fame, and had him exhaust some to as high a vacuum as his pumps would take. These re-exhausted bulbs now show a sensitiveness equal to those of the first four which proves exclusively that our contention is correct. For the work which we demand from these bulbs they are not sufficiently sensitive and we would be glad therefore if you will re-exhaust them. You certainly should be able to put them in as good condition as the aforesaid San Francisco glass-blower."

The testimony discloses that the glass-blower referred to heated the tubes under an asbestos hood almost to the collapsing point of the tube while they were being exhausted. The references of the prior art which reveal that a lamp may be made to collapse by heating under an asbestos hood leave no room to doubt this testimony. Such heat was sufficient to heat to a certain degree the metal electrodes as well as the walls of the tube, thereby driving off from the electrodes as well as the walls some of the gases occluded therein. The energy of the discharge of the De Forest tube was low. The bombardment was probably not adequate to heat the anode to a temperature even approximating that to which it was raised by the Bunsen burner under the asbestos hood. Consequently, little, if any, occluded gas would escape from the anode and the gas clean-up effect probably tended to im-

prove the vacuum more than it was caused to deteriorate by the molecules of gas that escaped from the anode. The tubes were thus enabled to function substantially above ionization voltages without substantial ionization.

Upon the issue of priority, too, I think the plaintiff must fail. In the contest in the Patent Office between Arnold and Langmuir upon this issue the Examiner of Interferences awarded priority to Langmuir. The Examiners-in-Chief arrived at the same conclusion but for reasons conflicting with those of the Examiner of Interferences. The Commissioner of Patents awarded priority to Arnold. The Court of Appeals of the District of Columbia decided in favor of Langmuir for the reasons stated by the Examiner of Interferences and the Board of Examiners-in-Chief. I am in accord with neither of the divergent views expressed by the Examiner of interferences and the Board of Examiners-in-Chief but, generally, with the reasoning and conclusion of the Commissioner of Patents. The defendant asserts that Arnold is entitled to the date of November 1, 1912. Upon that date Arnold, who because of his training and experience in the matter of electrical discharges in vacuum and upon the recommendation of Dr. Robert A. Millikan, had been theretofore employed by Western Electric Company to aid in making possible transcontinental telephone service at the opening of the San Francisco Exposition, was shown by Doctors Jewett and Colpitts a DeForest tube that had been brought by DeForest to the Western Electric Company a day or so before. Arnold examined the audion and tested its performance as a repeater of speech currents. It functioned well with weak currents but choked, distorted the speech and blue hazed when increased plate voltage or loud speech currents were ap-

plied. Though Arnold had been engaged in perfecting a different device of his own to be employed for telephone relay purposes, he instantly saw that the performance of the tube which made it too unstable in its existing state for a telephone repeater was due to ionization and that this could be removed by increasing the vacuum. This he then disclosed to Colpitts and Jewett. He also understood and then explained to Colpitts that the hot cathode would emit electrons in the high vacuum, that they would be subject to the space charge effect and that it would require high plate potentials to obtain the desired electron flow from cathode to anode. Corroboration of the oral testimony of Arnold, Colpitts and Jewett, if needed, is to be found in the fact that every act of the Telephone Company from that time on is consistent only with the intended use of the audion made more rugged and with a higher vacuum in its transcontinental service. Arnold's conception of the invention, consisting in the full performance of the mental part of the inventive act, was complete. Nothing remained to be done but to give the device practical embodiment with reasonable diligence. If, in view of the fact that those skilled in the evacuating art knew how to reduce to physical form Arnold's mental conception, a physical reduction of his conception to practice was necessary, and I think it was not, McCormick Harvester Mach. Co. *v.* Minneapolis Harvester Works, 42 Fed. 152, 155. Otto *v.* Linford, 46 L. T. (N. S.) 35, this requirement was performed by Arnold with reasonable diligence, thus giving to him an effective date of November 1, 1912. He obtained, knowingly, in that month with audion 7-A a current of 3 milliamperes at 80 volts without substantial ionization. Again, Arnold met the requirements of reduction to practice in April and May of 1913.

In the tubes of these experiments 250 volts were impressed upon the plate without ionization effect. The tubes used in Philadelphia in the fall of 1913 functioned well for many hours, one as long as 267 hours as commercial repeaters. The fact that the output energy of one of these tubes was less than that of the usual, original DeForest tube does not negative its being a tube of the patent, for the output energy of claim 26 is likewise less than the output energy of the usual, old DeForest tube. Moreover, it seems to me that other claims of the patent, for example 11, which was an original claim, differs from 26 in the same way and only in the same way that claim 26 differs from the original DeForest device.

Langmuir began his experiments in August of 1912. He now asserts and the defendant denies that he then obtained a pure electron discharge substantially unaffected by positive ionization but concedes, XQ380, that though he now knows that he did then obtain such a discharge he did not know it then. This lack of contemporaneous knowledge denies to his August work any effective value upon the issue of priority. Robinson on Patents, Sec. 79, p. 121. In November Langmuir made other experiments but these he concedes were for the purpose of ascertaining the accuracy and existence of certain laws of physics. I find no evidence that he then thought of applying the scientific principles in which he was interested to any practical result in the useful arts. Consequently, there is no satisfactory evidence that Langmuir had a conception of the device of the patent before the end of November. "It is not while the creative energies are at work shaping and sharpening the idea of means that the conception of the invention becomes perfect. It is when these energies have ceased to act, when the idea stands before the mental

vision of the inventor as clearly as a concrete invention before the eyes of an observer, that the conception is complete and the work of reduction is ready to begin." Robinson on Patents, Sec. 379. Tested by this rule even the statements of Langmuir to Coolidge in December, 1912, did not reveal a complete idea of means and, consequently, did not disclose a complete conception within the meaning of the patent law. It was not until March 21, 1913, as I read the record, that Langmuir's conception or idea of means to a useful end began to take shape. He then made a record of it in these words: "Now what I intend to do is to construct an audion which will operate entirely and exclusively on the electron discharge. I shall attempt to get the vacuum so good that positive ions are present in negligible amounts." It is not necessary to inquire when the conception became complete and his idea reduced to practice for Arnold had had the conception long before and had proceeded diligently to reduce it to practice.

The bill of complaint in this case must be dismissed.

(sgd) HUGH M. MORRIS, J.

January 3, 1928.

IN THE

UNITED STATES CIRCUIT COURT OF APPEALS,

FOR THE THIRD CIRCUIT.

GENERAL ELECTRIC COMPANY,
Appellant,

v.

THE DEFOREST RADIO COMPANY,
Appellee.

No. 3799.
March Term, 1928.

APPEAL FROM THE DISTRICT COURT OF THE UNITED STATES FOR THE DISTRICT OF DELAWARE.

(Filed October 3, 1929.)

Before BUFFINGTON, WOOLLEY and DAVIS, *Circuit Judges.*

Per Curiam.

The issues raised on these appeals were fully discussed in the opinion of the learned district judge and we agree with his conclusions. The decrees are, accordingly, affirmed on his opinion.

BUFFINGTON, *Circuit Judge,* dissents.

IN THE

UNITED STATES CIRCUIT COURT OF APPEALS,

FOR THE THIRD CIRCUIT.

GENERAL ELECTRIC COMPANY,
Appellant,

v.

THE DEFOREST RADIO COMPANY,
Appellee.

No. 3799.
March Term,
1928.

APPEAL FROM THE DISTRICT COURT OF THE UNITED STATES FOR THE DISTRICT OF DELAWARE.

Opinion of the Court.

(Filed November 11, 1930.)

Before BUFFINGTON, WOOLLEY and DAVIS, *Circuit Judges.*

BUFFINGTON, *J.*

In the Court below the General Electric Company charged the DeForest Radio Company with the infringement of four patents. On final hearing that Court held one of the patents valid and infringed and the other three invalid. By appropriate steps its so holding was brought before this Court for review. Without entering into detail, we may say that, save as to patent No.

1,558,436, the reasoning, conclusion and decree of the Court below commend themselves to us and we affirm the same. In the case of patent No. 1,558,436, we feel the Court below committed error in holding the patent invalid and dismissing the bill.

As usual in litigation over a patent of great commercial value, the vast mass of expert speculation, the protracted argument covering days and with briefs that in the aggregate covered several hundred pages, the case, on reargument, narrowed to the simple question of the patent paternity of what is known commercially as the Langmuir tube. The Court below held the tube had no patent paternity and to that question we now address ourselves. The subject-matter of the patent and the general features of the pertinent art are set forth at length in the comprehensive opinion of the Judge below and by reference thereto we avoid the necessity of present restatement.

Laying aside for the present technical language and scientific discussion and confining ourselves to simple statement, the Langmuir tube is a tube in which for example the gaseous conductor incident to a Fleming valve and a DeForest audion is dispensed with and a vacuum substituted therefor.

In the patent sued on, No. 1,558,436, granted October 20, 1925, to Irving Langmuir, assignor to the General Electric Company for "electrical discharge apparatus and process of preparing and using the same," the specification states:

> "The present invention relates to electrical *vacuum* discharge devices, and it comprises devices in which the electrical current is carried by negative charges called electrons, emanating from the

cathode, independently of *gaseous ionization* such as occurring, for example, in the ordinary Roentgen tube.

"My present invention comprises improvements in electron-discharge apparatus which make possible a *high load capacity* and operation with the *highest voltages*, but the invention is also applicable and useful for moderate loads and moderate voltages."

Existing objectionable incidents to the use of gassy tubes and the erratic, non-determinable action of gas are pointed out as follows:

"In order to distinguish electron discharge devices made in accordance with my invention from the prior art, I will explain briefly the character of a *pure electron* discharge as distinguished from a discharge through *ionized gas*. In a Geissler tube, and in a Roentgen or Crookes tube the conduction of current is accompanied by and depends upon *gas ionization*. Without a certain *minimum amount of gas* a Roentgen X-ray tube ceases to operate and as this minimum is approached the resistance of the tube steadily increases.

"The passage of an electric current across a tube ordinarily involves the movement of negative charges called electrons which, under the influence of the impressed voltage, pass from the cathode to the anode through the *vacuous space*. If these electrons when moving above a certain velocity collide with *gas molecules* they tend to ionize the molecules, splitting them up into electrons and larger and more slowly moving ions. Under these circumstances the phenomena of conduction across the tubes are the result of the action and interaction of the electrons and the ions; these phenomena are in general *erratic and non-reproducible*. The cathode under these conditions is disinte-

grafed, technically it is 'sputtered', which causes its rapid destruction. As *gas ionization* continues at higher voltages a *blue glow* may appear. The bombardment of the cathode by positive ions also causes heating of the cathode. The ionization of gases at low pressures by collision with electrons occurs at definitely determinable voltages, these voltages being known as the ionization voltages. *These voltages are different for different gases.* In the case of gases such as nitrogen, hydrogen, oxygen, argon, helium and neon, they are of the order of magnitude of fifteen to twenty-five volts."

Describing the DeForest audion and differentiating it from the alleged invention of the patent, the specification says:

"The phenomena above described as being characteristic of devices involving *gas ionization* are taken advantage of in an incandescent cathode device with three electrodes known as the 'Audion.' This device has been used as a receiver for radiotelegraphy and depends in its operation upon the rapid change of the discharge current when *gas ionization begins.* This point depends upon various *accidental* conditions which cause such irregularities in the operation of various devices apparently identical that sometimes only one of a considerable number can be used. Ordinarily the gas ionization in the audion begins to be important somewhere between 20 and 30 volts."

Describing the Fleming valve and its limitations, the specification states:

"Another discharge device previously used to some extent was the *Fleming valve.* This was a two-electrode tube which, so far as I am aware, was always used at voltages well below the volt-

ages at which positive ionization by collision occurs. It was not evacuated in such a manner as to permit it to be used at voltages materially above these ionization voltages without manifesting substantial positive ionization effects."

Referring to high voltage, the specification makes this statement:

"No prior hot cathode devices are known to me operating with currents as great as above 5 milliamperes with voltages as high as about 200 volts; indeed no prior discharge devices are known to me operating in a practically usable manner and without substantial positive ionization effects with currents as great as about one-tenth of a milliampere with voltages as high as about forty volts."

Specifying some of the differences and advantages of the alleged invention, the specification states:

"In devices made in accordance with my invention *gas ionization* is either entirely *absent* or is negligible and a discharge takes place which is *distinct* in its characteristics from the described discharge taking place in an *ionized gas*. The cathode is not heated by the discharge itself. Blue glow, glass fluorescence and in fact all readily visible indications of a discharge are ordinarily absent."

Referring to the evacuation of the tube, the specification sets forth:

"For the evacuation of the device the glass walls of the tube are carefully heated to as high a temperature as the glass will stand without softening and in general the most approved methods of incandescent lamp exhaust are used. The evacuation of the tube preferably while still heated is carried out by means of a suitable evacuating means, for

example, a Gaede molecular pump, which removes *vapors as well as gases* * * *.

"The evacuation of the device should be preferably carried to a pressure as low as a few hundredths of a micron, or even lower, but no definite limits can be assigned. * * *

"It is also true that when the anode has been carefully freed from gas, residual free gas, even if present in a sufficient amount to cause some gas ionization when the apparatus is first started, does little harm, as it is quickly removed by the gas clean-up effect when the device is operated."

Claim 12, which is,

"An electrical discharge device, comprising a gas-tight-envelope, an electronemitting cathode, an anode *deprived of ionizable gas* and a discharge controlling conductor, the space in the envelope being evacuated to a pressure not substantially in excess of a few hundred thousandths of a millimeter of mercury, said device being characterized by the fact that when operated below saturation and materially above the ionization voltages, the current is controlled by *space charge* substantially unaffected by positive ionization."

is typical in character of the alleged invention.

Does the defendant use a tube answering this general description? We think it does and that in giving up the old gaseous tube and using one of the "very high vacuum," a change which it announced in its statements to the public, we have a virtual admission of the essential difference between the two tubes. The tube of this disclosure is aptly described as "non gaseous" and "of a very high vacuum" by the defendant when putting it on the market, as follows:

"The tube consists of a highly evacuated vessel, cylindrical, rather than bulbular, in shape enclos-

ing the three elements, grid, plate and filament in the form of the old type T tubular DeForest tube with which amateurs are familiar. The plate is of nickel, cylindrical in shape and surrounds a helical grid also of nickel. The filament is a crimped tungsten wire passing through the center of the grid exactly as it did in the old style type DeForest tube. The chief difference between this tube and the type T tube of similar mechanical construction is in its evacuation. The old style type T was an *ionic or gaseous tube* very unstable in operation and requiring a variable 'B' battery. It had the decided disadvantage that after continued use the tube would get 'hard' and require more 'B' battery until it reached such a state as to be inoperative. The new 'VT' tube, like the DeForest standard tubes to-day, is purely an electronic tube exhausted to a *very high vacuum*, so that it is non-gaseous and will stand very high plate potentials. When used as a detector, however, a battery of 20 to 40 volts is sufficient to give the proper plate current although voltages of 80 to 100 may be used without detrimental effect upon the tube. The 'B' battery moreover, is not critical in adjustment and, therefore, a fixed battery may be used and is used for all practical work. * * * The gaseous type tubes are, however, no longer being manufactured."

Turning next to the question on which the validity of the patent depends, we inquire first as to its usefulness, for the constitutional power to create the monopoly of a patent in that regard conditioned "to promote the progress of * * * useful arts" and the Congressional enactment in pursuance of the Constitution is that "any person who has * * * discovered any new and useful" etc. For in the final analysis, use, usefulness, is the acid test, the SINE QUA NON of patent grant.

The unusual degree of usefulness of the tube may be assumed. The defendant by its use evidences its usefulness and has, we have seen, adopted it and ceased making "gaseous type tubes," and the Court below, after its exhaustive study of the art, aptly described the tube, and we agree with its estimate, as an agency which "because of its stability, reproducibility and power has made possible radio broadcasting, modern radio reception and long distance telephony."

Seeing then we are here dealing with a progressive step which next to the telegraph, the telephone and the wireless, is probably one of the most far reaching and beneficent in human progress, there can be no question of a non-gaseous, vacuum tube's usefulness. Such being the case, is it novel? The simple fact is that we see such a tube in universal use to-day; we know in the quoted language of the Court below of its "stability"; of its "reproducibility"; of its "power." We know that these elements have, as stated by the Court below, made "possible radio broadcasting, modern radio reception and long distance telephony." Indeed the fact that a non-gaseous vacuum tube makes possible the present improved practice shows that such practice did not exist before the Langmuir tube and that no other device or devices, all important as they may have been in their spheres, did either singly or collectively produce the present practice. The patent office recognized that. In the opinion of The Board of Examiners they found, in affirming the decision of the Examiners of Interferences, that "Langmuir was the first to conceive and the first to reduce."

While all the vast mass of knowledge testified to in these records was open to everyone to use, the simple fact remains that the non-gaseous tube of modern use did not occur to scientists. Every one of the two hun-

dred and sixty-six words in Lincoln's Gettysburg Speech is found in the dictionary; most of them in the Bible., But it remained—not for Noah Webster or even the Prophets of old—but for Abraham Lincoln to take these isolated words and so use them conjointly as to produce the most remarkable combination in literature.

We do not disregard or minimize the all important part of DeForest's audion and Fleming's valve play in the utilization of them in the Langmuir tube, but in spite of such high value, neither of them, in isolation or conjoint use, gave the world the tube here in question and it remained for Langmuir to so couple and coordinate the two by means of eliminating gas and using vacuum as to produce the tube here involved. What scientific credit is due to DeForest or Langmuir or to what patent tribute Langmuir subjected himself in thus using their devices are questions not before us.

Moreover the statement in the Commercial Circular of the DeForest Company that gas was an element of operation, was in accord with the then scientific belief. In 1911 Gernsback, an experienced savant, wrote that in the audion "the operating principle is the shattering of a column of conducting gas by a received electrical impulse."

The function of a gaseous tube as a conductor was stated by the Circuit Court of Appeals of the Second Circuit in 243 Fed. Rep. 565, where Fleming's valve and DeForest's audion were considered, in these words: "The 'gaseous medium' of the audion is nothing but the commercial vacuum of the ordinary electric light bulb—air being a gas, and the bulb containing some residual air. In other words, defendant uses the same 'vacuous vessel' that Fleming does." And in its opinion it stated that it was asserted in that case that the audion was "an ap-

paratus in which the bulb contains a substantial amount of gaseous medium essential to the operation of the device." To the same effect is the testimony of Langmuir, of which we find no contradiction, that

> "In the devices of the old art, in the DeForest audion, the pressure was continually changing. It sometimes increased and it sometimes decreased. Both things went on and there was an evolution of gas, water vapor would come off the bulb and be decomposed by the filament and it would generate gas. Gases would come out of the electrodes. Positive ions would bombard the walls and the electrodes and would drive gas off."

It will also be noted this Court in its able and exhaustive statement of the art in 21 Fed. (2) 918, said: "We observe that at the time of both the DeForest and the Armstrong inventions the only audion tubes in use were 'gassy' or 'soft'."

That its action was eccentric, is shown by DeForest's statement:

> "In the first place, anyone who has had considerable experience with numerous audion bulbs must admit that the behavior of different bulbs varies in many particulars, and to an astonishing degree. The wing potential wing current curves for different bulbs, or even for the same bulb at different times, under different conditions (filament temperature, etc.) vary widely.
>
> "What may appear to be a fixed law for one bulb may not hold for another."

On the other hand, the current in Langmuir is practicable, steady, reproducible at any particular voltage.

It further appears that the Langmuir tube has a great advantage when it comes to replacement. When a tube

is defective, another of the same type can be bought and placed in the same socket. Not so with the audion. It required frequent replacement and where replacements were made it was necessary to readjust throughout the circuit. In that respect the proof is:

> "XQ35. What practical effect would harmful ionization have upon an audion amplifier such as, for example, as is used in the telephone line?
>
> "A. The worst immediate effect would be as to uniformity of operation, which would make continued adjustments necessary and would interfere with the replacement of one device by another, that is to say, when one tube burned out and another were put in an amount of ionization that would interfere with uniformity of operation would make it necessary to readjust throughout the circuit to take care of the substitute tube."

As to the replacement, the proof is that

> "Another consequence of this uniformity is that replacement of the tubes without changing the apparatus becomes possible. That is particularly important in telephone repeaters and in radio devices both of the receiving and transmitting type. One wants to know that he can replace a burned-out tube with a new tube without having to make substantial changes in the apparatus."

It will also be noted that the whole trend of the art was against the use of a vacuum, and even after Langmuir had shown its use, it was deemed impractical. Thus in a paper of 1914 Wehnelt and Leibreich said that ionization persisted in the best vacuum they could get.

Moreover, it is of great present significance that the then view of DeForest himself was against Langmuir's use of the vacuum, he then stating in a paper read by him

before a scientific body: "I believe, however, Dr. Langmuir has, by working into these high vacua and the high potentials necessitated thereby, pursued the less promising of the two paths of research." The record shows no explanation, comment or retraction by him of this statement.

Such being the general state of the case, has the defendant by evidence overcome the prima facies of the patent? We think not. As said by this Court in 159 Fed. Rep. 948, citing the Barbed Wire Case, "the burden of proof upon this part of the case rests upon the defendant, and every reasonable doubt should be resolved against it." And in our view the crux of the case is one of fact, namely, whether the use of a vacuum in the combination of the claim was Langmuir's novel disclosure. We are not concerned with scientific theories and speculations as to what might have been done or what could possibly have been done for, as well said by the Circuit Court of Appeals of the Second Circuit in 298 Fed. Rep. 582, we sit "not as scientists, but as weighers of evidence." But we are concerned with the fact whether the combination of the claim which Langmuir disclosed was new. That some had bombarded anodes of X-ray tubes to get some of the gas out of them; that others had heated bulbs or used pumps to lessen the gas, may all be true, but none of them had produced the commercial tube which Langmuir gave to the public. And such actual contribution in use and not theory and possibility of speculation is, and of right should be, the decisive factor in patent reward. As was said by the Circuit Court of Appeals of the Second Circuit:

> "The keynote of all the decisions is the extent of the benefit conferred upon mankind. Where the court has determined that this benefit is valuable

and extensive it will, we think, be difficult to find a well considered case where the patent has been overthrown on the ground of non-patentability."

We regard as of high evidential significance the statements made by the defendant in its circular to the public, already quoted. It will not do to brush aside and ignore it on the suggestion it was the work of some enthusiastic subordinate or sales agent. It was a deliberate statement of a great mechanical company of its ceasing to make and market a superseded article and to thereafter make and market a new and different one. No such change would in business practice be made by subordinates, but was, in the nature of things, the mechanical, scientific and commercial determination of a great business organization. In this statement the defendant recognized a "non-gaseous," highly vacuum tube as new. As we have seen, it differentiated it from its "gaseous" tubes up to then made and publicly announced that such gaseous type tubes would no longer be manufactured. And indeed, that no such non-gaseous, highly vacuum tube existed is shown by the fact that the testimony of experts and the laborious research by the Judge below, whose industry is proverbial, did not disclose any such tube as both parties to this litigation now make and contend for the right to make, existed or had advanced the arts in question to this new standard of theretofore non-attained efficiency.

Such being the case, the defendant is driven to take the position—which found favor with the Court below—that in view of what existed in the prior art, that it required no invention to so utilize these things in the prior art to produce a non-gaseous, highly vacuum tube, and that this great progressive step was due simply to the art's natural advance and improvement.

But in point of fact no such advance toward a non-gaseous tube, as we are now told was to be looked for in the art, was actually made by the art. We would not be misunderstood. Advance, inventive and non-inventive, was being made in the art, but their efforts were in other directions. We would not detract from the great advance made by DeForest and exemplified by his audion and by Fleming with his valve, but great as these steps were—both separately and collectively—and we regard them as the foremost in the advance of the art in the sphere here involved—the gaseous tubes still continued to be used and the art generally regarded gas as incident, if not, indeed, indispensable to their use.

Indeed, had the art followed the caution of DeForest heretofore quoted, we would have no vacuum tube, a situation akin to that referred to by this Court in the Turbine case, 202 Fed. Rep. 932, where we said:

> "Finding, then, as we do, that the disclosures of the Moorehouse patent had no helpful bearing or practical effect on the impulse turbine art, and supported in that conclusion by the fact that its vagueness is such that fair-minded witnesses in this record greatly differ as to what its disclosures really are, we are not warranted in attributing to it any effect in the way of vitiating, or even minimizing, the work of Curtis."

Now as it seems to us, the art, although it did not exactly know how the gas in gaseous tubes acted and just why it was able to so conduct, nevertheless continued to use it and regarded it as the indispensable means of conducting. As against this firmly entrenched teaching and practice of the art, Langmuir's suggestion of eliminating gas as a conductor was a radical change and even more so was not the substitution of some other tangible con-

ductor, but the disclosure of supplanting the tangible gaseous conductor by the intangible conductor of a vacuum. Vacuums, per se, were of course known. DeForest's audion and Fleming's valve were equally known, but the suggestion of dispensing with gas and utilizing a vacuum between the two was as novel in practice as it was unlooked for in result. Indeed, shortly before the patent in suit was applied for and even though the use of a vacuum may possibly have been suggested, the director of the Research Laboratory stated in a paper read before the American Institute of Engineers: "In connection with this work of Fleming's, we have studied the effect of vacuum on the current, and also found that the presence of gas is necessary for this negative discharge." And that Langmuir's use of high vacua did not appeal to so practical and eminent a scientist as DeForest was evidenced by his statement, heretofore quoted, made even after Langmuir had made known his process publicly,—"I believe, however, that Dr. Langmuir has, by working into these extremely high vacua and the high potentials necessitated thereby, pursued the less promising of two paths of research." For the defendant to now contend that the use of these extremely high vacua by Langmuir was simply the natural and to be expected growth of the art is to credit the ordinary art with a scientific capacity which a master of the art like DeForest did not himself possess. If it was an obvious thing, as the Court below believed and decided, for the ordinary art to do away with gas and gaseous tubes and substitute high vacua therefor, surely such an extraordinary mind in that art as DeForest, when confronted with the substitution, would not have pronounced high vacua a mistaken path. Had the ordinary art followed the advice of this super ordinary adviser and leader and discarded the suggestion of high vacua, it

would seem so far as the universally used non-gaseous tube is concerned, it would not be in use today.

But it is contended by the defendant and the Court below so held, that all that Langmuir did was simply to vary in degree the prior use of the vacuum and that a mere difference in degree does not constitute invention or, to use the defendant's contention, the Langmuir tube is "nothing more or less than the identical thing of the prior art with possibly a little higher vacuum, depending on the specific use to which the devices is to be put." Assuming the correctness of this general proposition, we think it is not applicable to the present case. In considering change in degree, the test is not the quantum or minimum of change made but the quantum of change in function and result which such change, great or small, effects. A great change may effect but a slight change in function and result, while a slight change may effect a radical difference in function and effect. The effect, the practical progress and use in the arts, are the aim and end of patent grants and where great results follow a change, the slightness of the change tends to emphasize and make all the more remarkable, unexpected and inventive the disproportionate result the slight change effects. It was the slight turn of a screw and the closer proximity of the diaphram that made the telephone diaphram the carrier of speech and gave Bell the due reward—not for the slight turn of the screw but for the great effect it wrought. But a vacuum, or indeed change of vacuum, isolated and standing by itself, is not the Langmuir invention, but it is a working tube in which all the elements, cathode, plate, vacuum, so co-ordinate and interwork that current flow is not affected by gas. We say not affected by gas, because of necessity an absolute vacuum is an impossibility, but the degree of vacuum is such the current flow

is no longer objectionably affected by gas. Just what the degree of vacuum shall be is dependent on several elements and, as stated in the patent, cannot be exactly stated. In that regard the specification says: "The evacuation of the device should be preferably carried to a pressure as low as a few hundredths of a micron, or even lower, but no definite limits can be assigned."

So regarding what we believe to be the basic question in the case, we limit ourselves to the foregoing statement of our reasons for our conclusions. But in thus limiting our discussion, we deem it proper to say that the numerous questions and considerations advanced in the case in other particulars, have been duly considered.

The degree of the Court below holding this patent invalid is reversed and the record remitted with instructions to enter a decree that the patent is valid and infringed.

The Opinion of Judge Woolley.

IN THE

UNITED STATES CIRCUIT COURT OF APPEALS

FOR THE THIRD CIRCUIT.

GENERAL ELECTRIC COMPANY,
Appellant,

v.

DEFOREST RADIO COMPANY,
Appellee.

March Term,
1928.
No. 3799.

WOOLLEY, *Circuit Judge*, dissenting:

I am constrained to dissent from the judgment of the court holding the Langmuir patent No. 1,558,436 valid. I have the same trouble that other tribunals have had throughout the twelve years of the patent prosecution and five years of the patent's life in finding precisely what Langmuir invented. My trouble, like that of others, has been increased by the difficulty which attorneys for the patent have had in defining the invention and by the difference between their definitions and the claims of the patent.

This is more than a mental disturbance, for manifestly a patent to be valid must relate to some invention, something patentably new and useful, and must disclose the invention so that a court, looking through the eyes of those skilled in the art, can see what it is.

The art—really two related arts—is that of wire and wireless telephony, the latter commonly called radio. The invention relates generally to an electron discharge device comprising the familiar vacuum tube in which the customary electric current is carried by negative charges called electrons from the cathode to the anode, sometimes associated with a grid, and relates particularly to a vacuum space so free from gases as to avoid ionization. If the parts and principles of the mechanical construction were new and the gas evacuation old, there might be invention; and also if the structure and its principles were old and the gas evacuation—high vacuum—were new, still there might be invention. But the essential parts and principles of the mechanism, comprising a tube, cathode, anode and grid, were old, and high vacuum in the tube also was old. So the inventor was forced to admit the presence of these old elements, yet, still insisting he had created something new, he was compelled to avoid the common art terms applicable to these elements and particularly that of "high vacuum" in disclosing his invention and use technical terms which, as I understand them, mean the same old things. With this necessarily general preface to a highly complicated situation arising out of a difficult art, I come to the matters in hand.

In an effort to find what Langmuir invented, it is well to begin at the beginning. I shall therefore turn to his application for a patent, for in that instrument must appear the substance of the invention as the basis for subsequent amendments and for the patent as it eventually matured.

A recital of the prosecution of a patent application through the Patent Office is dreary reading yet, in this instance, it shows quite clearly that even the applicant

was far from certain what he had invented. Naturally I hesitate to say this about Irving Langmuir, a great physicist, yet, saying it with entire respect, I am convinced that the history of the application establishes that fact and therefore is pertinent to the ever present inquiry: What did Langmuir invent?

The patent issued on October 20, 1925. The application was filed on October 16, 1913; renewed March 14, 1916. These are critical dates. The original application contained five claims; two for process of removing ionizable gas from vacuum electron discharge devices, that is, in plain words, for obtaining a high vacuum, and three for methods of preparing such devices, and no claims for discharge devices themselves. The specification conformed to these claims, referred to the art, stated the problem, disclosed construction adapted to the operative principle of such tubes and showed how they can be "evacuated" of gases by heating the glass walls, heating and bombarding the metal parts thereby expelling occluded gases, and drawing off both free gases and expelled gases "by a suitable evacuating means, for example, a Gaede molecular pump."

It should be noted that when the application was filed in 1913 the radio art was in its infancy but that, in 1925, when the patent issued, the art had attained an amazing growth. It is pertinent to inquire what happened to the application during this span of twelve years during which the mysteries that had enveloped the early art were largely dispelled and replaced by a broad knowledge of its principles.

After the application was filed in 1913 it lay practically dormant for several years, the applicant filing enough amendments by additions and cancellations to keep it alive. Amendments to the specification occurred as fol-

lows: two in 1913; eight in 1914; one in 1915; five in 1916; three in 1917; three in 1919 and forty-five in 1925, the year the patent issued.

Amended claims were filed and additions thereto and cancellations thereof made as follows: four in 1913; fifteen in 1914; twenty in 1916; five in 1917; nine in 1919; five in 1921 and forty-two in 1925, the year of the patent.

Analyzing these amendments, it appears that the five original claims (which were for process and method) were at different times wholly cancelled. Late in the year 1913 Langmuir first made claim to invention of a structure or device, that is, to invention of a tube. This he did by four claims. The first was amended four times and cancelled in 1925. The second also was amended four times and cancelled in 1925. The third was amended four times and was not cancelled. The fourth was amended once and cancelled in 1925. Of the thirty-two claims allowed in the issued patent, four are for method and process, being amplifications of the original method and process claims cancelled; twenty-eight are for a device. Of these device claims one was filed by amendment in 1913; one in 1917; nine in 1919; three in 1921 and fourteen in 1925, the year the patent issued. Bearing on the question whether Langmuir knew and disclosed in 1913, or indeed in succeeding years, what he had invented, it is significant to note that during twelve years, and mainly in the latter part of that period when the art had grown and reached a high stature, he rewrote, by sixty-seven amendments, the major part of his specification and cancelled all the original method and process claims and by one hundred amendments added, changed and cancelled claims until finally he was allowed the thirty-two claims of which twenty-eight, the claims for a device, are entirely new. It would be in-

structive, yet impossible within the permissible bounds of an opinion, to trace the progressive changes from the method and process claims of the original application to the device claims of the matured patent. But device claims having been allowed, they inevitably bring into the case certain devices of the prior art of which two are presently pertinent.

Long before Langmuir applied for a patent, Fleming, an English inventor, brought into a very feeble art a practical electron discharge device, comprising a cathode and anode in a vacuum tube. Also long before Langmuir's application, DeForest improved on Fleming by producing an electron discharge tube which he described as an oscillation detector and called an "audion." The improvement consisted in adding a grid to Fleming's elements. The construction and functions of both devices are given in an elementary way in the opinion in Westinghouse Electric & Mfg. Co. *v.* DeForest Radio T. & T. Co., 21 Fed. (2d) 918, 919. The audion as conceived by Fleming and improved by DeForest at once became and has ever since continued to be the basis of the modern art of transmitting sounds great distances both by wire and through the air. Just here dates are important. A patent for the audion (No. 879,932) issued to DeForest in 1908. The audion vacuum tube was therefore in existence and its principles of operation presumably known by Langmuir when in 1913 he filed his application for a method of evacuating such a tube, although he had not seen one until that year. In 1912 or 1913, the American Telephone & Telegraph Company, committed to the operation of transcontinental telephony by the opening of the San Francisco Fair, acquired rights under the DeForest patent and, first exhausting the gas and heightening its vacuum, used the DeForest audion

as an amplifying telephone relay, thus making possible the first transmission of vocal words from coast to coast by wire. In 1917 the DeForest Radio Telephone Company, assignee of the DeForest patent, granted (with certain rights reserved) a license to the Western Electric Company to make, use and sell the invention for certain purposes with the right to grant sub-licenses. In 1920 the General Electric Company, the plaintiff in this suit and the assignee of the Langmuir patent in suit, acquired through mesne conveyances a sub-license to make, use and sell the DeForest audion, DeForest Radio T. & T. Co. *v.* Radio Corporation of America, 20 Fed. (2d) 598, 599, 600, which (probably with a heightened vacuum) it did on a vast scale until the DeForest patent expired in 1925, the year in which the patent in suit, after twelve years of travail in the Patent Office, issued to Langmuir, assignor to the General Electric Company, for an electron discharge tube including the essential parts and now universally accepted principles of the Fleming-DeForest tube. The Langmuir patent now completely covers the field previously occupied by the audion of the expired DeForest patent, and will, on the decree of this court, continue to cover it for twelve years more; hence the importance of this litigation.

Turning to the patent as it issued, the specification must first be looked at, for it contains some references to the behavior of electricity in a vacuum tube, old and well known, which are necessary to an understanding of the case. First there is a description by words and diagrams of mechanism for a vacuum tube. If new, this, it would seem, is unimportant as the specific mechanism is not claimed. Its importance resides in the fact that the patented device comprises the three elements of the general mechanism found in the art—the cathode, anode

and grid, variously positioned in a vacuum tube to get the best electrical result—and in the fact that, as I read the record, these three elements, separately and in combination, operate on the same principle in which they operated in the art. Describing their operation, as the art then knew it, Langmuir said:

> "The passage of an electric current across a tube ordinarily involves the movement of negative charges called electrons which, under the influence of the impressed voltage, pass from the cathode to the anode through the vacuous space. If these electrons when moving above a certain velocity collide with gas molecules they tend to ionize the molecules, splitting them up into electrons and larger and more slowly moving ions. Under these circumstances the phenomena of conduction across the tubes are the result of the action and interaction of electrons and the ions; * * * The cathode under these conditions is disintegrated, * * *, which causes its rapid destruction * * * The bombardment of the cathode by positive ions also causes heating of the cathode. The ionization of gases at low pressures by collision with electrons occurs at definitely determinable voltages, these voltages being known as the ionization voltages * * * (It should, for later use, be noted here that Langmuir said nothing about gas being a supposed medium for conducting electrons from one electrode to the other.)
>
> "If for a given cathode temperature the voltage is sufficiently high to call all the electrons emitted or liberated at the cathode to be drawn away, then a further increase in voltage produces substantially no change in the current. The current thus determined is called the saturation current, and the range of operation in which the current is substantially independent of the voltage or approaches this condition may be called the saturation range

> or more briefly designated merely as saturation. If for a given cathode temperature the voltage is not high enough to cause all of the electrons which are emitted or liberated at the cathode to be drawn away, the operation occurs in a range below the saturation range. Operation in this range may be spoken of as operation below saturation."

Predicated on these two definitions of ionization and saturation Langmuir by claim 2, which has been treated in this litigation as a typical claim, said that his invention is:

> "A discharge tube having a cathode adapted to emit electrons and an anode adapted to receive said emitted electrons, the tube walls being fashioned or shaped to permit the direct passage of a useful proportion of said electrons from cathode to anode, the gas content or residue of said tube and the relation of the parts of the tube being such that the tube is capable of being so operated in a range, below saturation and materially above ionization voltages that the space current is governed or limited by the electric field of said electrons substantially unaffected by positive ionization."

That, as I read it, simply means "high vacuum," for a tube properly fashioned and shaped by skilled workers and highly (thoroughly) evacuated of gases—free and occluded—will in conjunction with a two electron group or with a group of two electrons and a grid produce these results; both groups, then and now, being in common use for different purposes by the art and by the plaintiff itself.

For the purposes of this case, vacuum means gas evacuation, high vacuum means vacuum above the ionization point, and, by the same token, a high vacuum

tube means a non-gaseous tube. If the language of the claims means high vacuum, it is prior art, for the art was entirely familiar with the fact and effect of such a vacuum; and if prior art, Langmuir invented nothing.

When the patent came into litigation in this case in the District Court of the United States for the District of Delaware the learned trial judge, having trouble with the claims, endeavored to get from the plaintiff a definition of the invention, asking time and again, as did this court on appeal: If not high vacuum, what is the invention? An answer to this question seemingly had its difficulties. The plaintiff, of course, could not say that the invention was high vacuum alone, or high vacuum in combination with Fleming and DeForest parts alone, for that would be an admission of old art and would instantly avoid the patent. It was forced to admit that the Langmuir device included all these old elements but claimed it included "something else." So, eventually, in order to show this something else—something new—it produced, under the insistence of the trial court, this carefully constructed definition of Langmuir's invention, on which the case was tried below and on which it was first argued and decided in this court on appeal:

> "The Langmuir invention is a coordination of elements having a new functional relation between various factors, producing a new result. It is not a matter merely of maintaining a certain vacuum, far less of *producing* a certain vacuum which will be destroyed the moment the tube begins to operate. It involves primarily a relation between the shape, size and space relation or 'geometry' of the parts of the tube and the nature and pressure of the gas therein contained, coordinated and adjusted with respect to the conditions of the electric circuit."

That, I surmise, would be a bad patent claim. However, as it was intended to describe the invention more clearly and more definitely than Langmuir had disclosed it in the patent claims I shall take it as it is written and try to find what it means. I discern in its generalization three factors: (1) gas pressure in the tube; (2) "shape, size and space relation or geometry of the parts of the tube"; and (3) the relation of one to the other.

The first factor of gas pressure, or, more properly, the lack of it, if it means anything, must mean a minimum of gas. This in turn means high vacuum. If it does not mean high vacuum there is no new vacuum factor of invention in the device, for low vacuum was old and that is an end to the case. If it does mean high vacuum then again it is not new, for high vacua, their uses and effect and how to produce them, were long known and practiced in the art.

The second factor, or "geometry," of the physical tube elements is not, so far as the claims reveal, involved in the invention. The physical elements themselves were old. This the plaintiff admits. Though differing in shape from some others, they are not claimed to be inventively novel in themselves. Indeed, each claim describes the invention not so much by its parts as by its characteristics of operation and results—characteristics inherent in any electron discharge tube possessing a high vacuum. Nor was this an inadvertence for when the Examiner, on rejecting certain device claims on prior art references, said:

> "If applicant's device is an improvement over the reference he should define the difference by structural limitations," the applicant (Langmuir) replied by saying:
>
> "The 'structural limitations' in this case are to be found in the *difference of vacuum.*"

So, thus far, the invention, with old parts and a high vacuum, gets back to the question whether there was invention in the "difference" between low vacuum and high vacuum, a difference existing in and known to the art.

The third factor, the relation of the two factors of gas pressure and physical parts, appears nowhere in the claim unless it be implicit in the words "the gas content or residue of said tube and the relation of the *parts* of the tube being such" as to produce a certain result. (Gas pressure is scarcely a *part* of a tube.) If it is so implied, Langmuir cannot claim invention by implication. The claim therefore is void for inadequate disclosure. If it is not so implied, there is no claim for the third factor.

Whether I am right or wrong in this analysis of the plaintiff's statement of Langmuir's invention or in my disposition of its elements is not important for the validity of the patent depends not on the plaintiff's conception and definition of the invention but on the claims of the patent.

So I come back to the claims of the Langmuir patent to find Langmuir's invention. But before doing that I am arrested by still another entirely new definition of Langmuir's invention, this time made by the court in its opinion. The court did not adopt the plaintiff's definition of coordinating elements with functional relations but, stating that a non-gaseous electron discharge device did not exist before Langmuir, found the invention to reside in his producing a non-gaseous tube in place of a gaseous tube of the prior art or, in other words, in substituting a high vacuum for a low vacuum, the very thing which all along the plaintiff was forced to avoid in its definition because it was old. Without conceding its predicate, I agree with the court's succinct definition of

the invention; but as the invention so defined was old I cannot agree to hold a patent for it valid.

It now appears, and I say this with entire respect, that in interpreting and sustaining the patent broadly for a non-gaseous tube the court has given the plaintiff more than it ever dared to claim. A high vacuum or non-gaseous tube being old, the plaintiff knew that an admission that the invention was a non-gaseous tube and nothing else would defeat the patent. Langmuir also must have known that a non-gaseous tube was old for otherwise, if he had believed he was the first to conceive and make one, he could, and doubtless would, have claimed it in a half dozen words: "A non-gaseous discharge tube," or "an electrical discharge device with a high vacuum tube," whereas in his original application for a patent he made no claim for a tube of that kind or, indeed, for a tube of any kind, the inevitable inference being that at that time he thought all he had invented was a new method or process of gas evacuation, that is, a new way to produce an old thing. But that the plaintiff realized the necessity of claiming for the invention something more than a high vacuum tube or non-gaseous tube is evidenced by its earnest and repeated contentions that Langmuir's invention, while including a non-gaseous tube—high vacuum—admittedly old, included "something else," that something else being disclosed by the remainder of the long claims and interpreted in its quoted definition. The plaintiff nowhere and at no time has claimed that Langmuir invented a non-gaseous tube *per se*. And wisely so, for it well knew that, while not in universal use, non-gaseous tubes were in commercial use before Langmuir for some purposes and that gas evacuations were as thorough as the instrumentalities of

the art in 1913 would effect, and that was substantially above the ionization point, which is the crux of this case.

Returning to the patent claims and using claim 2 for convenience, it appears that the invention is an electron discharge tube which is capable of being operated below saturation and above ionization voltages. Langmuir called this a "pure electron discharge device"—"pure" because unaffected by gas ionization which is either entirely absent or negligible.

Electricity is an elusive subject. Therefore I shall, for the immediate purpose, restate in plain words, if I can, the theory of ionization.

Ionization is an effect produced by passing an electric current through gas which remains in a vacuum tube when it has not been thoroughly evacuated. The myriads of electrons, when passing from cathode to anode above a certain velocity, collide with and break up the molecules of gas present and charge the resultant broken parts or ions with positive charges of electricity. Thus electric reaction is inevitable. The ions (with their positive charges of electricity) fight against the electrons (with their negative charges) in the normal flow of the latter from cathode to anode resulting, at high voltages, in a blue glow which is the indication of bad action, a thing to be avoided. The central point of this statement is that ionization occurs at certain voltages in an electron discharge tube when, not being thoroughly evacuated, it contains air or gas, whether gas free in the tube or gas occluded in its parts and liberated by heat during operation. The amount of ionization depends upon the amount of gas present. Langmuir prescribed in his specification that occluded gas should be expelled from the tube parts; from the tube by heating its glass walls; from the cold electrodes by electron bombardment—the liberation of

gas by the electric discharge itself; and from the incandescent cathode by the heat of an electric current; all old; and after this, that both the expelled gas and free gas should be pumped out of the tube during the heating process (old) by "a suitable evacuating means (old) for example, a Gaede molecular pump," then a new German invention.

Thus the capital requirement, if not the sole requirement, of Langmuir's claimed invention, is as nearly as possible to withdraw from the tube all gas, free and occluded; in other words, to obtain as high a vacuum as possible. When that is done ionization is avoided and a pure electron discharge follows. Was this new with Langmuir?

Langmuir was met in the Patent Office with the Law Examiner's statement that:

> "It is apparent after a review of the record that there is no single element which is broadly novel in the assemblage of elements making up an electron discharge device of the character defined in the issue. *An evacuated tube having therein an incandescent electron emitting cathode and an anode was old prior to the filing of Langmuir's application, and methods of attaining high vacua, sufficient to give a relatively pure electron discharge in a properly designed tube were also well known and available to persons skilled in the art.*"

Was that statement of the Law Examiner correct? I think it was. Just here occurs my sharpest departure from the opinion of the court which is based, as I have before stated, on what I am constrained to believe is an erroneous theory or finding that all discharge tubes before Langmuir were gaseous and that Langmuir's invention is a non-gaseous tube.

If that was his invention, clearly he must have been the first to conceive it and reduce it to practice. That the Examiner was right in saying that high vacua in electron discharge tubes were old before Langmuir and that a pure electron discharge—the inevitable result in a high vacuum non-gaseous tube and an impossible result in a gaseous low vacuum tube—also was old is sustained by many prior publications and patents. The same prior publications and patents contradict, I think, the court's holding that Langmuir was first to make and invent a non-gaseous tube. They are so numerous that it would not be permissible to quote them in an opinion. I shall therefore do nothing more than cite a few of them, ranging from 1881 to 1912, found in the record and to be used by anyone who should desire to check up this statement or who may be charged with the duty of retrying the issue. They are: Lilienfeld, Fleming, Doane, VonBaeyer, Bissel & Hagen, Malignani, Edison, Dwyer, Duncan, Leonard, Soddy, Thatcher, Child; illumined by the testimony of Waterman and Chaffee.

On these references I stand; and on them I would hold the patent invalid for want of invention.

Passing from the literature and patents of the prior art as affecting the validity of the patent for want of invention, I come to the question of prior use. The trial court found the patent also invalid because of prior use by DeForest on evidence as to which there is little dispute on the facts as distinguished from inferences. The test is the voltage at which ionization ordinarily occurs in a "gassy" tube. It is given at from 20 to 30 volts. That is not disputed; they are Langmuir's figures.

Prior to August, 1912, DeForest was the electrical engineer of the Federal Telegraph Company of California and was engaged in developing the transmission and re-

ception of messages by radio. In this work he used his oscillation detector or audion then normally having a gas content. It was a "gassy" tube. But desiring to use it not as a detector but as an amplifier, as later it was almost universally used and indeed as made for that use by the plaintiff itself under license and by the Westinghouse Electric & Manufacturing Company, its sublicensee, he had the audion exhausted of gas as far as it was possible in that day. That is, he sought and obtained as high a vacuum in the tube as existing means would produce. When the vacua were too low and the amplications poor he complained to the manufacturer and had the tubes re-exhausted. During that period (1910, 1911 and 1912) the Federal Telegraph Company used DeForest's amplifying audion at 54 and 67½ volts. This was possible only because he had exhausted the tubes of gas, which otherwise would produce ionization at 20 to 30 volts, and thereby heightened the vacuum above that danger line. This was "high vacuum" within the definition of vacuum above the point of ionization and was therefore high vacuum within the sense of those words as used in this case. It was not so high as that later attained by more modern means, for instance the Gaede molecular pump, which had just come into the art at the time of the patent application, referred to by Langmuir in his application and invented not by him but by Gaede. I agree with the court that DeForest did not then understand the change in operative principle for in later years he expressed views contrary to those advanced both before and after that time. But DeForest did change the vacua of his tubes in changing their function from detectors to amplifiers. Whether he knew the principle of the change is of no consequence. The fact is he did it. And he did it before Langmuir. And by

doing it he got rid of the ionization of low vacuum and obtained, and put into commercial practice for nearly three years before Langmuir, the very electron discharge of Langmuir's claimed invention.

What I have said about the device claims applies equally to the method and process claims.

On the subject of validity as involving invention I shall conclude this phase of the discussion by referring very briefly to the claimed advance made in the art by Langmuir's invention, matter with which the plaintiff very earnestly began and ended discussion in its brief and at the argument and matter by which the court was impressed. Admittedly, when invention is in doubt—yet *only* when it is in doubt—favorable reception by the art may be placed in the scale. As the four judges who heard this case have divided evenly on the question of invention, I shall, for that reason only, assume there is doubt as to invention. The plaintiff says that today everybody uses "the Langmuir tube," a name given it not by the art (as the plaintiff frankly admitted at the argument) but by the plaintiff itself; that Langmuir, seeing through the mysteries of the art, made an invention that revolutionized the industry and made possible the transmission of sounds through the air for great distances which without his invention would be impossible.

Much litigation in respect to the radio art has drifted to this circuit. Oddly enough, in every case the plaintiff has claimed for his invention the whole credit for its growth. I am satisfied from the number of cases we have heard that the whole credit for the amazing advance of the radio art cannot be given to any one invention or even to a few of them. In truth, the art is the product of innumerable impulses. The original impulse was, of course, the vacuum tube appearing years

age in the incandescent lamp art. Another impulse given in the incandescent lamp art and transferred to the radio art was that of the Just and Hanaman unstable squirted tungsten filament displacing Edison's bamboo filament; still another was Coolidge's method for obtaining a filament of pure tungsten, strong and stable. Impulses in the radio art itself came from many inventors. At one time there were seven thousand applications for patents pending in the radio section of the Patent Office. To mention only one or two inventions, they include discharge devices of the Fleming two electrode type and the DeForest type with a grid added to Fleming, the feedback circuit invented at different times by DeForest, Armstrong, Langmuir and Meissner. There are many more, without any one of which it has always been said by the particular inventor that the art would have gotten nowhere. And now the plaintiff here says the same of Langmuir. Important and indeed great as some of these inventions were, no one of them is entitled to all credit for what has been accomplished in this great art, for the art has been impelled forward by hundreds of inventors and thousands of skilled workers. What Langmuir claims to have done—procured pure electron discharge above ionization voltages in tubes of the DeForest type—appears to me to be the natural growth of the art, begun by others before Langmuir and by them reduced to practice with means then available, and developed to their later perfection during the twelve years of his patent prosecution through the Patent Office.

I thought after the argument, and still think, the Langmuir patent invalid because of lack of invention and prior use. If I am wrong and the patent really involves invention then, again, I think it invalid for, as I read the evidence, Langmuir was not the first and original

inventor. On this point, to avoid repetition, I refer and subscribe to the opinion of Judge Morris holding on evidence substantially greater than the evidence in the interference proceeding that, if invention, Arnold was the first and original inventor.

And so this court, one judge dissenting, affirmed the decree of the District Court, on its opinion, holding the Langmuir patent invalid.

In due course the plaintiff filed a petition for rehearing based on this proposition:

> "In simple language, Langmuir's invention consisted in taking out the conductor (gas) which was in the Fleming valve and the DeForest audion and putting nothing in its place; he dispensed with what was regarded as an essential element in the operation of the tube (gas) and by doing so made a tube which worked infinitely better."

The petition was allowed and the reargument was based on this entirely new statement of Langmuir's invention made for the first time four years after suit was brought, five years after the patent was issued and seventeen years after the application was filed. Of course if the facts asserted were facts established by the evidence there would be no doubt about what Langmuir did and no doubt that it was invention and, if claimed, no doubt he was entitled to a patent.

The plaintiff rests its proposition upon its own statement that "Both Fleming and DeForest depended upon the conductivity of gas as the fundamental basis of the operation of their tubes." It makes this statement without distinguishing between detectors and amplifiers and supports it by carefully selected quotations from scientific publications in the early days of the art ranging from 1905 to 1912 (one in 1915) when scientists were feeling

for the theory of electron movement in electron discharge tubes, some of whom based it on conduction by rarified gases or air, some on conduction by ionized gases, and some not on conduction at all but on free passage of electrons through space in a high vacuum, that is, in the absence of gas or air. And in addition the plaintiff to support its statement points to an adverse criticism by DeForest in 1915 of Langmuir's "extremely high vacuum" quoted in the court's opinion. The plaintiff ignored all the testimony on the subjects of prior art high vacua and pure electron discharge, which means absence of gas as a conductor, their advantages and uses, to which I have previously alluded with citations.

Of course, if the belief and practice of the art were that gas conducts the electrons, that gas therefore is necessary to conduction and Langmuir discovered it to be wrong, that in fact gas is an enemy to conduction, and omitted gas as an element in his tube yet obtained the same or a better result, clearly he made an invention. These are the things which now the plaintiff and also the court say he did. But Langmuir did not say so. If that was his invention he should have disclosed it in his claims for we are called upon to judge the patent on Langmuir's disclosures, not on the plaintiff's definitions of his invention. To be sure, he did refer in his specification to several tubes—the Geisler tube and the Roentgen X-ray tube—"whose operation depends upon gas ionization." He might, more or less correctly, have added to the list detectors with gas content, then and now in common use for certain purposes, whose usefulness depends on their sensitiveness and their sensitiveness on gas content. But he nowhere said in his patent that before his invention electron discharge tubes used for amplifying purposes in order more faithfully

to reproduce sounds (one of the purposes of the DeForest audion and the thing we are dealing with in this case) depended on low vacuum or that the art regarded as an essential element of such a device, gas as a conductor, for he probably knew the contrary was true. To show that the plaintiff's last definition of Langmuir's invention is without foundation in the evidence I refer to, but shall not repeat, what I have said about prior knowledge and prior use of high vacuum tubes. I shall endeavor, very briefly, to show that Langmuir by his own words contradicts the plaintiff's last definition of his invention and refutes the theory on which the court has in part based its judgment.

In Langmuir's original specification he stated that when there was enough gas in the tube to become ionized by the discharge of electrons "The positive ions (gas molecules) *take part* in the *conduction* of current, giving at first erratic readings on measuring instruments connected in circuit," which is what the plaintiff now says. Continuing, he said, that the audion, the DeForest tube, was a device that took advantage of that phenomenon. *But he cancelled the quoted statement before the patent issued.* At the trial he was examined with respect to that statement in his patent application and was asked whether the sentence would be true if it read: "The positive ions take part in the conduction of current by acting as *conductors* or carriers of current." He answered: "In my opinion the sentence would have *no sensible meaning* if the word 'conductor' was left in for *it is inconceivable that ions could be conductors of current.* I will, therefore, confine myself to the case where the positive ions act as 'carriers.' With this correction I can say that the statement would not have been true."

With this cancellation and explanation Langmuir rested. Neither by amendment nor in his testimony did he again advert to a prior art theory of gas conduction which the plaintiff now says "was regarded (by the art) as an essential element of the operation."

In the interference proceeding Langmuir testified with respect to the early work of Lilienfeld, as follows:

> "Lilienfeld proved beyond question, I think, that he obtained discharges, in some cases at least, in which the effects that he measured *were not dependent upon gas ionization.* * * *
>
> "Lilienfeld probably succeeded in obtaining a discharge *high vacuum substantially free from effects of positive ionization* in the device he described in his 1910 paper * * *
>
> "Lilienfeld in his experiments of 1910 heated the walls of the vessel, *he reduces the gas pressure to a low value,* and in some of his experiments *he heated his electrodes* by *electronic bombardment* * * *
>
> "*Heating of glass and electrodes, and exhaustion to low pressure,* are elements which were used by Lilienfeld and were known *prior* to Lilienfeld's article * * *
>
> "Factor No. 1 which I gave in answer to XQ84, viz., that the bulb should be heated *during* exhaust to a temperature materially higher than the operating temperature, was used by Lilienfeld in much of his work * * *
>
> "Factor No. 4, which is that which I gave in the first part of my answer to XQ87, refers to the lowering of the pressure to such a point *that a further lowering brings about no further change.* In many of Lilienfeld's experiments, this condition *was realized.*"

Von Baeyer stated as early as 1909 that his "experiments were of course carried out in the highest possible

vacuum to avoid the influence of ionization." Langmuir admitted that "Wehnelt claimed that * * * currents of the order of 10 milliamperes could be obtained even in the highest vacuum."

Referring to an interview with Richardson in 1912 Langmuir said:

> "Richardson * * * expressed himself as confident that even in the highest vacuum thermionic currents could still be obtained."

Langmuir admitted in the interference proceeding that "prior to 1912 (the year before his application) there were some experimenters who took precautions to remove gases from the walls, from vessels and from electrodes."

This, I think, shows that the reargument, based on an incorrect premise, should leave undisturbed the court's first finding that the patent is invalid.

The plaintiff, however, prevailed. The court reversed its previous decision and will now enter a decree holding the patent valid. From the opinion announcing its judgment, in so far as it will reverse the decree of the District Court on the first (Langmuir) patent in suit, I dissent.

This is a long dissenting opinion. In view of the gravity of the court's decision and its effect upon the art I make no apology for its length. I frankly admit that it is written with the hope that it will arrest the attention of the reviewing court.

A true Copy:

Teste:

Clerk of the United States Circuit Court
of Appeals for the Third Circuit.